

PROTECTIVE ROOF SYSTEMS FOR ARCHEOLOGICAL SITES IN MEXICO

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ABSTRACT

When an archeological site is discovered and excavated, all its remains are usually incomplete and have not been maintained so, in a very short period of time, they can suffer important deterioration and destructive processes due to environmental factors. These structures have lost their “organic” character, to become fragments with different material conditions to those they were originally designed and used with, which make them highly vulnerable. To revert the negative effects of environmental factors over archeological ruins, in many of these sites, protective canopies or shelters have been installed under the logic of modern building techniques. Many of these roofs have been made with different materials, sizes or even visual and structural relationships with the archeological site, and of course have diverse degrees of effectiveness. Even though it is true that these new structures can protect, up to a certain degree, these heritage ensembles from climatic conditions, it is also undeniable that they generate other impacts that must be assessed. There are several aspects that should be considered during the design process to achieve an adequate material and visual integration with the site as it has been defined in different international encounters and documents dealing with proper built heritage conservation. The design of these new elements must be sustained on solid theoretical concepts, considering principles such as reversibility, respect, harmony, authenticity and integrity when inserting modern structures in preexisting cultural contexts. After analyzing several canopy or cover roof solutions adopted in different archeological sites in México, we have summarized a series of factors that influence the design of such elements that can be considered for future projects of this kind.

Keywords: protective canopies, shelters for archeological sites, built heritage conservation, preservation, protective roofs.

1 INTRODUCTION

There is a long tradition in the intervention of structures built in the past for their use, study and profit in our days, within which we can find archaeological ruins. In the case of Mexico, archaeological sites and monuments, as far as the law is concerned, refer to structures and material objects that were made or created before the arrival of the Spaniards in the 16th century.

Most part of Mexico's archaeological heritage, with the exception of very specific and limited cases, consists of buildings and settlements that are no longer habitable spaces in contemporary terms, due to various aspects such as the disappearance centuries, and even millennia ago, of the societies that created and occupied them, the systematic demolition of material culture which took place throughout the Spanish conquest, as well as to processes of obsolescence and abandonment or even destruction suffered when building new infrastructure or urban settings.

In our country, there is a wide diversity of archaeological sites and ruins which include entire cities such as Teotihuacan, extraordinary ceremonial centers in the Mayan region, structures beneath our cities, as is the case of the Great Temple in the heart of Mexico City, thousands of small pyramidal bases disseminated all over Mexican territory, as well as the highly vulnerable remains of Paquimé, settlement which was entirely built with Earth, in the northern part of the Country.



The richness of this archaeological heritage involves, at the same time, the need to protect and preserve it, a task of enormous magnitude, which grows whenever a new site is discovered and explored. No doubt that "...the problems to preserve and at the same time display on-site excavated archaeological properties is one of the most complicated challenges to deal with, since any action carried out in the archaeological space will contest its own existence, and the problems of each site is specific and unique" [1]. It is an increasingly contentious issue because, on the one hand, it is desirable to learn more of the past, to put the remains in the public light in order that current and future society may enjoy and learn from them, but on the other hand, that heritage is exposed to enhanced deterioration processes primarily due to environmental factors.

Many of these buildings, because of the fact of been covered by debris or vegetation for long periods of time developed, progressively, balanced environmental conditions, but once excavated and again "exposed", experimented new structural and material strains as well as different environmental exchanges which placed them in a situation for which they were never designed. The latter, implies the need not only to physically preserve such material remains, but also to create conditions for their optimal conservation in the long term.

Another aspect to consider when working on archeological sites, is the need of proper interpretation of the inherited remains; they are fragmented elements for which a coherent historical reading, based on recognizable data, must be established. An essential part of the presentation of archaeological heritage is related to the possibility of current readings of these artifacts from the past, understanding it can be even more difficult if they are removed, even for conservation purposes, from the environment and landscapes to which they belong:

As noted in the foregoing, the principles and policies of physical protection of archaeological heritage exposed on the sites should consider, preferably, the conservation of archaeological elements in their original context, turning to a multiplicity of reasons and aspects of diverse nature that first and foremost ensure their safekeeping, in contention to the different factors that can jeopardize their physical integrity and, for this reason, the authenticity of the site in general. [2]

In this sense, any intervention to protect this heritage, be it by means of its mere consolidation, or even the placement of a roof, should contribute, as far as possible, to the current interpretation of the place, as well as to establish the material conditions that favor such reading, in their own physical and geographical settings.

In this context, one of the main solutions that have been used to protect archaeological ruins, are covers or shelters of different sizes, types and characteristics, which have had diverse degrees of effectiveness. It is a resource used in the field of archaeology, initially to accompany excavation processes, subsequently to protect permanently specific elements of a site, but in more recent years it has become a device that is gaining ground, not only in Mexico, but in the whole world.

However, among the issues to be analyzed when these kinds of roofs are incorporated, are their shape and size in relation to the local landscape as well as to the heritage structures they cover. The addition of protective roofs in archaeological sites, which are becoming increasingly larger, can even come to have more importance than the remains that are to be protected. Recently, there are specialists who argue that the roof itself implies the decontextualization of the ruin:

Structures displayed under some kind of sheltering structure are put out of the original context even though they are still in situ. The lack of architectural forms

that gives the observer clear picture and contribute to the overall experience of the place is sometimes mayor problem with this kind of presentation projects. [3]

The issue of incorporating protective roofs on the archaeological cultural property is, with no doubt, of high complexity, so it must be resolved in an interdisciplinary manner, otherwise there is a risk of applying partial solutions that do not fully resolve the preservation of these sites, and even may produce other negative impacts.

Much has been discussed about the convenience of this protection technique, because they are structures that, in many cases, are not only physically invasive, but also of a high visual impact on the surrounding landscape that may disrupt the balance of the heritage remains with its environment. Problems such as the incorporation of foundation that destroy important parts of the archaeological remains to be preserved, wind acceleration and its effects on built or decorated surfaces, constant vibrations which are transmitted to the ground by columns that support large spans, changes of moisture and temperature conditions inside or under the roof, among many others, make it necessary to carefully study the environmental vulnerability of each site.

In some way, incorporating roofs in archaeological sites entails an unavoidable contradiction since, on the one hand, the objective is to protect 'fragile' elements from environmental conditions, but at the same time, it is desirable not to alter the fragmentary state that the material remains and their environment have [4]. So, there is no one way or only method to address the problem in general, but rather it requires specific solutions that should arise from the knowledge and analysis of the site, through a process of conscious design committed to sustainable preservation [5] of cultural heritage and its natural and cultural environment.

2 ROOF TYPES FOR ARCHAEOLOGICAL SITES

In the case of Mexico, although the use of covers or protective roofs in archaeological sites and areas has evolved, it is still a subject that requires greater research, but mainly, of careful evaluation of this kind of interventions, to reach conclusions that allow the application of more accurate criteria which may contribute to minimize negative impacts on these sites. Despite institutional efforts to establish better conditions for preservation, the truth is that in the case of our country there is still not enough experience to address design guidelines for coverings of archaeological sites:

Although it is obvious that components of sensitive configuration, that constitute heritage of great cultural and aesthetic value, must remain protected in association to their architectural and urban contexts, there are practically no technical guidelines to help archaeologist develop designs for covers. This has led to a chaotic situation in which every archaeologist, even with the best intentions, is whom decides on the placement of the cover, and only rarely achieves a harmonious coexistence between the new elements and the site. [6]

As it was previously pointed out, inter and multidisciplinary collaboration is essential, to be able to aid archaeologists, because roof design involves many disciplines, such as engineering, landscape design, conservation, architecture or climate control only to mention a few. Therefore, an initial analysis has been developed to identify the way in which the incorporation of protective roofs has been undertaken and to be able to draw conclusions that can support future guidelines and criteria for their design.



2.1 Temporary roofs

A first type of protective element for archaeological sites is directly associated to the excavation process itself. The use of lightweight covers which initially have a provisional character, are installed during the time that exploration, excavation and research work takes place at the site. In most cases, it represents the usage of lightweight structures, designed with materials such as canvas, plastic, tensioning ropes or cables, as well as steel or aluminum tubes that support corrugated metal or plastic sheets.

Due to its “apparent” insignificance for the site, these temporary elements usually do not pass by a specific design process, and most of the times are improvised. However, the very nature of excavation works with their meticulous procedures, limited resources, changing climate conditions, isolated location, make these research and restoration processes last for years, even decades, so protective covers are not that momentary. Despite this, there are little resources invested in the design and maintenance of temporary shelters, which also should incorporate progressive growth criteria. We must recall that archaeological areas and sites are elements that cannot be predetermined in their final form or extension, which are almost always quite irregular and conditioned to the findings themselves. Hence, the need for flexibility, modulation and adaptability to topographic conditions should be a basic principle for designing temporary protection elements.

2.2 Integrated roofs

An important part of archaeological heritage is constituted by buildings that were originally conceived as covered spaces, meant for ritual, administrative or habitable functions, and due to different circumstances, lost in time their roofs. Until the decades of the 1970s–1980s of the past century, the trend that dominated the intervention of such sites, favored the restoration of most of the built and architectural elements, as were their roofs. This led to different types of interventions, some of which fell in excessive reconstruction of the remains, what makes it even today, difficult to recognize the difference between the original structures and the rebuilt sections.

However, it is necessary to recognize that these type of roofs, were almost always very similar to those that originally existed, and their incorporation allowed a long-term protection of valuable elements not only of walls, but also decorations, floors, paintings, bas-reliefs, among others, in a more effective way than if they have had a temporary cover systems or, of course, remained uncovered.

More recently, the new trends in conservation and restoration of archaeological ruins, promote minimum intervention, favoring less the integration of complete architectural elements in pre-Hispanic structures. Parts of what must be preserved are the ruined landscape and avoid reconstructions that may alter the authenticity of cultural property.

Examples of this solution of integrating roof systems that are very similar to the original ones, can be seen in several sites, designed with different criteria. The Temple of Quetzalpapalotl, was restored by incorporating a contemporary roof that goes beyond just recovering the spatiality and lost volumes.

Another well-known case is the site of Mitla in Oaxaca, where a roof made of wood logs that resemble the original building system was added. In both cases, the main idea was directed to restore spaces, scales, textures, in other words, the whole architectural ensemble.





Figure 1: (a) The Temple of Quetzalpapalotl in Teotihuacan, after the restoration. The roof protected the vestiges of the site but at the same time altered conditions of authenticity; (b) Mitla in Oaxaca, also rebuilds the roof tops. (Photos: L. Guerrero.)

The idea of giving continuity to a type of roof similar or very close to the traditional systems, not only allows to keep in good physical, aesthetic and functional condition the cultural property, but also to extend a constructive tradition whose prolonged use over time does not invalidate it as a contemporary solution.

However, although the employment of these systems is fully compatible with the supporting structures, in most cases the design criteria has approached reconstruction, creating confusion about the values of authenticity that should be considered when intervening such structures.

Despite the former, it is a solution that can and must be re-explored, because of the benefits it represents as far as protection is concerned as well as improving the interpretation of the site, but incorporating much more obvious criteria for adequate integration and differentiation between old and new elements.

2.3 Focalized partial roofs

The placement of permanent roofs with independent structure over archaeological sites or ruins, not only for the physical protection they offer, but also to bring better conditions for visitors, is probably the most widespread solution applied today. It implies the use of small to medium size assemblies that are designed to cover specific elements of the ruins. Usually the remains to protect are those of greater importance to the site and are selected for their historic value, aesthetic quality or degree of conservation, so they are not exposed to environmental factors. These roofs are self-supporting structures, which may rest on the ruins themselves when the latter are sufficiently resistant, but also anchored on the adjacent ground of the excavation to protect.

The variety in the design of these types of roofs is huge, from structures made of steel, aluminum and glass that contrast with the archaeological environment, as is the case of the “Templo Mayor” in México City, to roofs built with local materials such as wood, palm leaves and stone, made to cover altars in the Mayan region. Also, mixed techniques have been used, which combine more resistant elements as concrete columns to support roofs made of wood and straw.



Figure 2: In the Great Temple site, discovered in México City's historic center, the incorporation of protective roofs was necessary in order to safeguard pre-Hispanic vestiges with original decoration. Not all the site was covered; rather, a selective criterion was applied, shielding only a few notable structures. (Photos: L. Guerrero.)

These types of elements achieve better levels of integration with the surrounding landscape and because of their size are physically and visually subordinated to the archaeological remains.

A field that is increasingly developing is the use of smaller shelters (micro-roofs) which by their weight and usage of regional materials, can be incorporated much better into the cultural context, without posing a risk to stability and reducing visual impact on the landscape. In most cases, the idea is to complete the construction system, much in a similar way to the ones that existed or, at least introduce a structure that is compatible with the characteristics of the pre-existing ones, as a means for adequate conservation. Successful examples of intervention with an important decrease of the physical and visual impact on the heritage environment can be seen in many sites of the Maya area, as Ek Balam, Mayapán, Kohunlich, Edzná and Coba, where small covers made with wooden or bamboo struts and stringers that support a mesh of guano palm (*Sabal Mexicana*) have been implemented.



Figure 3: Sites in the Maya area such as Kohunlich have been protected with small, lightweight covers, using natural materials which minimize the physical and visual impact on the structures. (Photos: L. Guerrero.)

2.4 Large protective structures

The use of large span structures to cover archaeological sites, made of steel and concrete has not become widespread in Mexico. While it is a growing trend around the world (see sites as Catalhoyuk, in Turkey or Kourion in Cyprus) in our country its implementation is still quite limited, even though we have a vast number of archaeological sites and ruins with huge areas of highly vulnerable material. The best-known case of large coverings is that of the acropolis of Cacaxtla, which proved to be very controversial because of the bad experience that it has represented, for more than two decades after it was built. The intervention in this important archaeological site, mainly built with earth, located in the State of Tlaxcala, in the center region of the country, included an enormous steel structure with metal panels for the roofing, with a surface of nearly 11,000 m², and throughout the years has produced a series of problems that must be pointed out:

- The destruction of adjacent structures for the construction of enormous foundations for columns and tension anchors.
- The acceleration of wind under the cover that increased erosion of the ruins.
- The removal of rain and hail from the roof top; the accumulation of ice after a hail storm made part of the structure collapse just a few years ago.
- Negative visual impact on the surrounding landscape.
- High maintenance costs.
- Drying and moisture loss of the earthen built heritage remains.
- Development of bird colonies, which inhabit inside and drop debris on the archaeological ruins.

There are other sites with large size roofs in Tamaulipas, Oaxaca and Guerrero, but even though they are smaller in relation to Cacaxtla, similar problems persist, like visual impact on the landscape, or the enhancement of deterioration processes due to micro-climate changes that affect the cultural assets that are supposed to be preserved. In that sense, the lack of institutional criteria to address this problem is evident, despite efforts the National Institute of Anthropology and History has made to improve the design of protective covers for archaeological property.



Figure 4: The large structure that covers the site of Cacaxtla remains the biggest intervention made over an archaeological site in the country. It has had negative effects in the long run over the ruins, to the point that its removal has been debated. (Photos: L. Guerrero.)

3 THE COMPONENTS

Regardless of the type of protective roof used for different functions and temporalities, these are constituted by a series of elements that interact directly with the archaeological remains, and therefore the impacts that these may have on the ruins must be assessed.

3.1 Supporting elements

One of the main problems facing the design of structures that are not part of an archaeological site has to do with the characteristics of the place where they are to be installed. Most of the structures that are used to cover large spans are based on designs with light-weight steel profiles, supported on posts or columns. This means that the roofs' dead load is going to concentrate on the less possible number of points on the ground, to avoid placing too many columns. This decision is especially important in sites built with earth, whose resistance to external loads is dramatically less than the industrialized materials.

3.1.1 The foundations

The first element to consider when installing protective roofs on archaeological sites (as in all buildings) are the supporting points on which the structure will rest, making it necessary to determine if the loads are distributed on natural terrain, or on the ruins themselves, when this is possible.

When it comes to lightweight roofs, for temporary protection purposes, that use wood, bamboo or other types of columns or vertical supports, it is common to bear them directly on the archaeological structure. If this is the case, such supports must be installed in points where the ruins are solid, stable and do not touch vestiges of a high aesthetic, historical or documentary value that could be affected.

When building bigger protective roofs, with large spans and using the less possible number of columns, support points that can concentrate great loads, are required. This means sometimes broad, well anchored foundations in the ground or alternative footings as micro-piles, that may be incorporated to reduce the contact surface with the ground, but they require a greater depth for anchoring purposes. This criterion requires several considerations in archaeological sites, since the ground may contain material remains in different layers, below, surrounding or adjacent to those that are to be displayed and therefore protected. In many occasions the new foundations involves the moving and even the demolition of archaeological structures of the site.

3.1.2 Vertical support

The elements which support the roof and at the same time discharge loads towards the foundation, can be isolated, continuous or a combination of both.

The vast majority of studied covers, sit on isolated supports or columns of different materials and shapes, but almost always trying to achieve the most slimness and lightweight possible.

This choice has to do with the intention that these components should interfere as less as possible with the visibility of the ruins from different angles. In this sense, posts of wood, bamboo or other plant origin material are often used for small span covers. Steel, on the other hand, for its resistance and relative lightweight is the preferred material for columns that support large-span roof systems, although the use of engineered and laminated wood is gaining ground.

The use of load-bearing walls is less frequent; almost always the designs choose to leave the perimeter open, to maintain good ventilation, which favors a more suitable



micro-climate under the roof. Sometimes, when the archaeological walls allow it, sections of new walls are built over the original ones, with similar material characteristics to support the roof structures on certain segments. An element that often is used is the lattice, not always as a structural element, which aims to mitigate and control the access of light, wind and rain water.

3.2 The roof

The incorporation of protective covers in archaeological remains implies that these will inevitably have an outstanding presence in the site. Except on rare occasions, covers or roofs never go unnoticed, that is why it is necessary to take a series of determinations in this regard. Even though there are some examples of roofs on archaeological sites which are intentionally very contrasting, which stand out due to their shape, color, and position, more than the remains themselves, there seems to be a consensus that the best approach is the use of simple, neutral roofs as far as possible, of regular shapes, leaving the stage to the ruins.

A factor associated to the former, derives from the complication that arouses in the design of large structures which, due to structural calculations, the use of prefabricated materials, as well as the interest to achieve homogeneous distribution of loads, the designs tend to generate symmetrical roofs with a simple plan geometry. If the dimensions of the components of the structure are balanced, it is easier to distribute loads in an even way onto the ground, as well as controlling the possible effects of environmental agents such as wind.

However, this consideration ignores the fact that normally excavated sites are neither symmetric nor possess qualities of spatial organization that will ensure that the decision to place vertical supports at a certain point will coincide with similar conditions in the rest of the archaeological site. This problem is enhanced by the fact that these locations are excavated and protected in stages, according to the ongoing process of exploration and conservation, which normally do not conclude with the opening of a site to the public, but continue for months or years; so, the shape of the protective covers should not be predetermined, but developed in function of the spaces and areas that must be protected.



Figure 5: The design of protective covers with “standard” criteria usually does not take care of specific conditions as proper rainfall eviction, maintenance requirements, energy needs or aiding visitors. The case in Tampico, Tamaulipas is a simple horizontal barrier that does not provide a more comprehensive solution. (Photos: L. Guerrero.)

The preferred materials to build the structure that will support the roof are wood and steel; the first for lightweight and relatively small roofs; the second, used both to cover small spans with light steel profiles, as well as large covers with trusses or spatial structures.

3.2.1 The form

The influence of the weather on the shape of the roofs is evident: large pitches in one or two directions or curved forms to enable easy removal of water, as well as to lighten the burden that the wind forces can transmit to the structure. Flat roofs are preferably used in short spans; while sometimes they have been used on great-sized covers, their risk of collapse by accidental loads makes them dangerous, as it happened back in May 2007 in Cacaxtla, because of the accumulation of hail.

3.3 Additional features

Covers must be complemented with a series of technical elements that include installations for the eviction of rainwater, electrical fixings to aid maintenance and lighting, cat walks (for large roofs) to service the structural components, among other factors. Unfortunately, in the majority of the analyzed cases, this kind of features are not even evaluated or considered during the design stage, which causes an accelerated deterioration of many of the structures and makes maintenance more difficult and costly. This is a huge oversight in the Mexican experience.

4 FINAL CONSIDERATIONS

From this overview, a series of considerations can be outlined after assessing information from direct experience, discussions with specialists, as well as consultation with institutions concerned with the conservation of archaeological remains. The main criteria to consider starting from the analyzed cases, are listed below:

Design with interdisciplinary teams. Given the complexity of the problem, it is inappropriate that the decision making and design process of protective roofs for archaeological sites rest in a few hands, as it has been until recent times. The integration of specialists from various fields of design, engineering, conservation, landscape, archaeology, among others, should always be the starting point, even in cases that are considered relatively “small”.



Figure 6: The design of the protective roof over the temple of Malinalco in the State of Mexico, was built with wood and palm leaves, and is a hypothetical reconstruction of the shape it had in Aztec times. (Photos: L. Guerrero.)

Conservation of the authenticity of the remains. Regardless of the type of cover to integrate, the main objective aimed to conserve the values of authenticity and integrity of the remains, must prevail. The principles of harmonic integration play an essential role in this category. This harmony is related not only with the image and form of the new components but also with the criterion of compatibility of the construction materials involved, as well as the additional features required for functional considerations.

Integration to the landscape of the site. The surrounding landscape is an integral part of the remains and their values to protect, so regardless the context, may it be an urban milieu, a rural setting or an isolated place such as jungles, mountains and deserts, the interaction with their natural and cultural equilibrium conditions, must be protected. The relevance belongs to the landscape and to the ruins, not to the protective cover that must, as far as possible be simple, austere, neutral and of low contrast in their design.

Technical compatibility with the structures to protect. The new structures must be compatible, as far as possible, with the buildings to protect, to make the interaction between materials and construction systems, physically and mechanically similar, to favor joint work not only from the static point of view referred to the handling of loads, but also with the movement dynamics derived from wind, water and eventual earthquakes.

Balanced bioclimatic conditions. Covers imply a change in the environmental conditions of the heritage structure to protect. The evaluation of the new conditions of humidity, sunlight, temperature or wind, among others, is of the utmost importance. Also, a gradual approach to adapt the remains to the new conditions under the roof, must be planned and assessed to minimize negative impacts.

Durability and maintenance. Regardless of the solution adopted to protect archaeological remains, the elements of the system will require constant care. Hence, the importance of using high durability materials and construction systems readily available on-site and of easy maintenance.

Any failure by small that it may be (a leak, for example) can have devastating effects on structures or decorations, especially if they are in isolated areas where the attention from operators can take time to arrive. In this sense, to apply traditional systems, best known in the region, with materials available in the vicinity, can be a determinant factor to keep a good operation of the protective elements.

Knowledge and adaptation to the technological context of the place. All built heritage was conceived and materialized based on specific conditions of time and space, which does not always prevail until our days. Learning about the technological possibilities that are available or can be reproduced on the site, is a necessary estimation to include in the design process, during its later implementation on the field and its necessary maintenance in the future.

Reversibility. The possibility of retiring the protective roofs and regain the previous condition of a site, should always be evaluated in the design process, which involves the use of structural elements that can be easily dismantled without affecting the archaeological remains. Bigger structures require more permanent elements which can make reversibility more difficult.

Overall impact assessment of the intervention. Any action undertaken on or within a pre-existing setting will have an effect or impact that must be assessed. A '0' impact is not possible, it is necessary to evaluate the positive and negative effects that any intervention can have on the heritage structure, to take appropriate decisions during the process of design and construction.

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