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The preservation of the architectural heritage of the twentieth century: the laminar structures of reinforced concrete.

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Abstract
The beginning of the 20th century brought a new typology of architecture based on the use of geometrical laws of nature, the use of a new material such as reinforced concrete, and the use of plastic calculus as a tool to mold continuous, adirectional structures, such as the long cylindrical shells of Eduardo Torroja or the hyperbolic paraboloids shells of Felix Candela.
This type of architecture allowed the creation of large diaphanous spaces of great plastic beauty due to its close connection with the laws of nature that generates them.
Little more than 100 years later we see how the necessary legal protection has not been given to these buildings to consider them part of the heritage and we are witnessing a process of disappearance of most of the structures that have defined an important period of modern architecture.
From this research we have made an inventory of the main structures made with these techniques and their state of preservation today and the possible measures for their possible rehabilitation, and real or virtual reconstruction through the use of digital tools, 3D scanners or lifting using photography, and especially its inclusion in the catalogs of buildings that are part of the architectural and cultural heritage.
The process culminates with the possible construction on a real scale of the models lost by digital manufacturing systems or the diffusion through augmented reality.

Keywords: World Heritage, Reinforced concrete, laminar structures, 3D Scan, Virtual construction.

1. Introduction
Throughout history, man has taken advantage of the close relationship between architecture, nature and geometry [1]. The result of this connection is the approach to beauty imitating the proportions of nature [2] or making the most of the resistant capacities of the materials both for their shape and for their resistance [3].
He passed from life in the existing caverns, to the construction of temples in the city of Petra, (Fig. 1) in which the mountain is excavated creating polyhedral geometric spaces almost perfect as the Tomb of the Urn (19 x 21 m) of the first century after Christ.

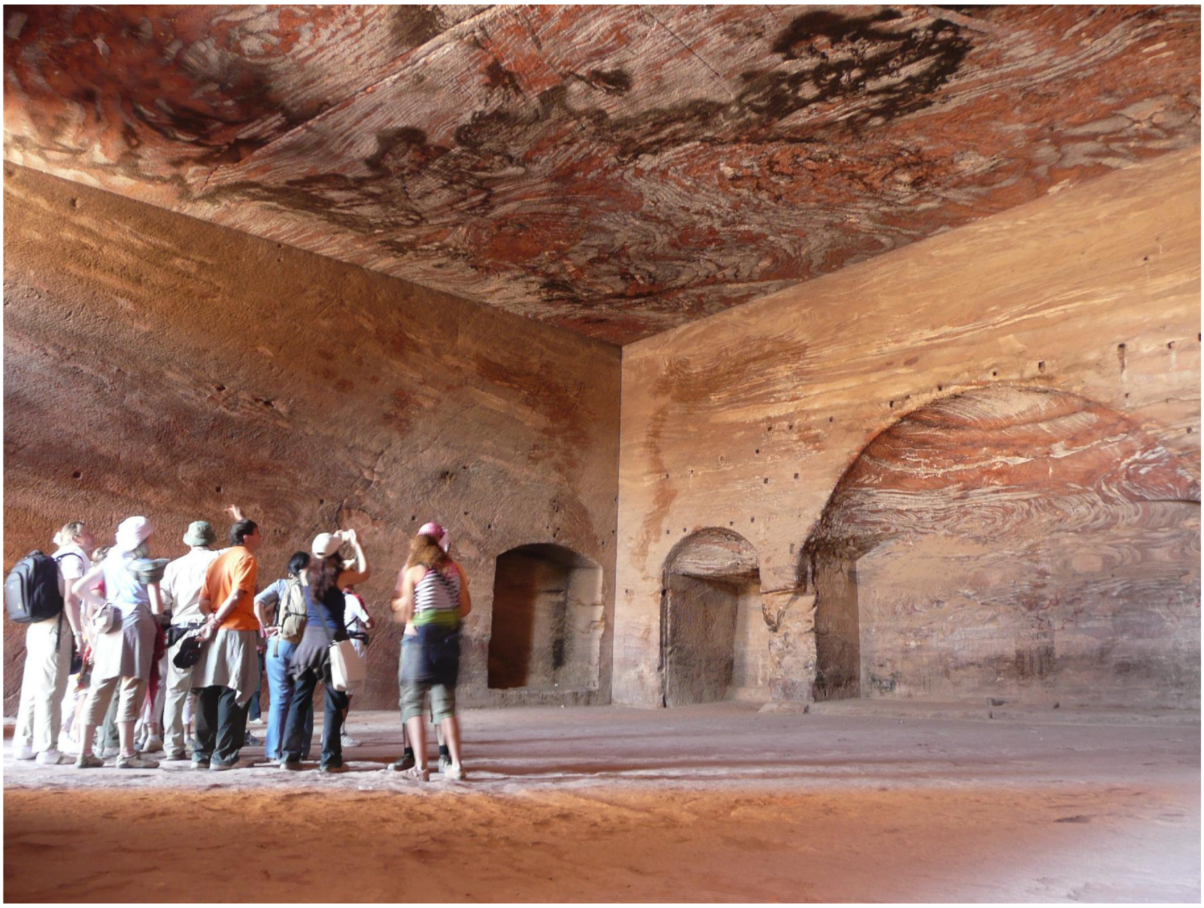

Fig. 1: Urn Tomb. Petra. Jordan

The need to expand the spaces of worship transforms from the lintel forms to the use of arches or triangular vaults as in the acropolis of Tikal (350 a.C) where the capacity of resistance to the cutting of the small flights of the lintel pieces is used. With the use of the semicircular arch, the barrel vaults, the pointed arches or the domes can cover increasingly larger surfaces at the expense of compensating the lateral thrusts created and knowing how to make the most of the shape of the pieces and of the set created using the geometry in both formal [4] as constructive [5] and as support for structural calculation [6], [7].

2. The reinforced concrete and the laminar structures.

The invention of reinforced concrete at the end of the 19th century and the beginning of the 20th century allows the creation of a new typology of buildings based on the geometric laws of nature, with the support of plastic calculation taking advantage of reinforced concrete as a building material and, fundamentally, its good behavior in the face of fire and economy, innumerable patents arise for its commercial exploitation. Before the First World War, the two construction companies that took the initiative in the theoretical and constructive study of reinforced concrete were Dyckerhoff & Widmann, founded in 1865, and Wayss & Freytag, founded in 1893; both German firms.

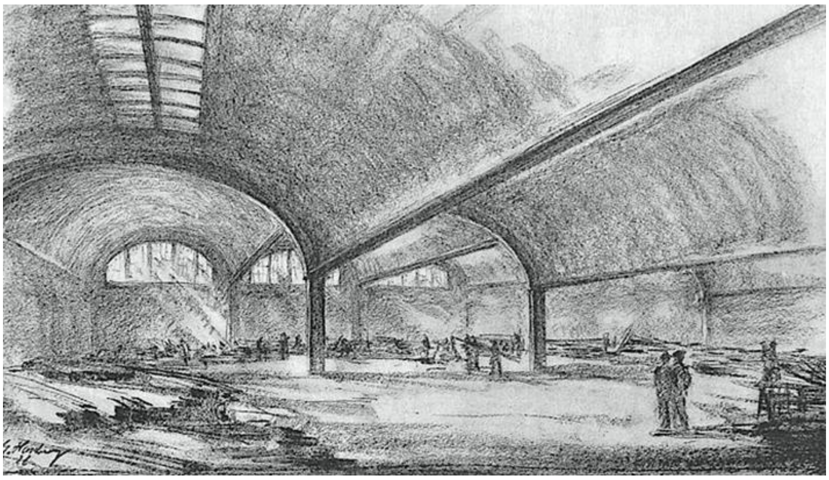

Fig. 2: Perspective of Dywindhalle. Fr Dischinger and U. Finsteerwalder. 1926 “Die Dywidag-Halle auf der Gesolei” Der Bauingenieur 7, figure 1, p.929 [8].

After the First World War, research on thin layers of reinforced concrete multiplied to try to find new methods of calculation, control and construction procedures, as well as to obtain more precise and scientific criteria to define the real behavior of these structural typologies. In 1922, the company Dyckerhoff & Widmann built, for the firm Optical Zeiss, a hemispheric dome to cover what would be the new Jena Planetarium (Fig. 3), similar to the first geodesic dome, executed for the first planetarium and built in it. year for the Deutsche Museum in Munich.

Fig. 3: Dome of the Jena Planetarium under construction, 1924. “Kuppelbau für das Planetarium in Jena”. Umschau Heft 38.

It will be in the field of utilitarian constructions, such as stations, markets, industrial buildings, etc., associated with their construction to this point in steel, where concrete will begin to develop as a material capable of competing in large structures. The unlimited formal possibilities of the sheets will oppose the need for rationality, the geometry that imposes its tensional and constructive analysis [9].

In this way, continuous and adirectional structures were obtained, such as the cylindrical vaults of Recoletos's Fronton of Eduardo Torroja in Madrid (fig. 4 & 5) or the hyperbolic hyperboloids of Felix Candela. This type of architecture allowed the creation of large diaphanous spaces of great plastic beauty due to its close relationship with the laws of nature that generate them.

Fig. 4: Interior view of the roof of the Recoletos Fronton. Eduardo Torroja 1935. Madrid. Spain.

In the Recoletos Fronton project, Torroja covers the rectangular space of the court and the stands by means of two long reinforced concrete cylindrical shells, 55 m long, each one with different circumferential arcs that start from the same height with vertical tangent and are at right angles, spacing a width of 32.5 m. For the execution of the shells it uses the same system, Zeiss-Dywidag [10], used by the German engineers. Dischinger and U. Finsterwalder [8] in the execution of the Grossmarkthalle in Frankfurt or the same one that used E. Freyssinnet in the hangars of Orly.

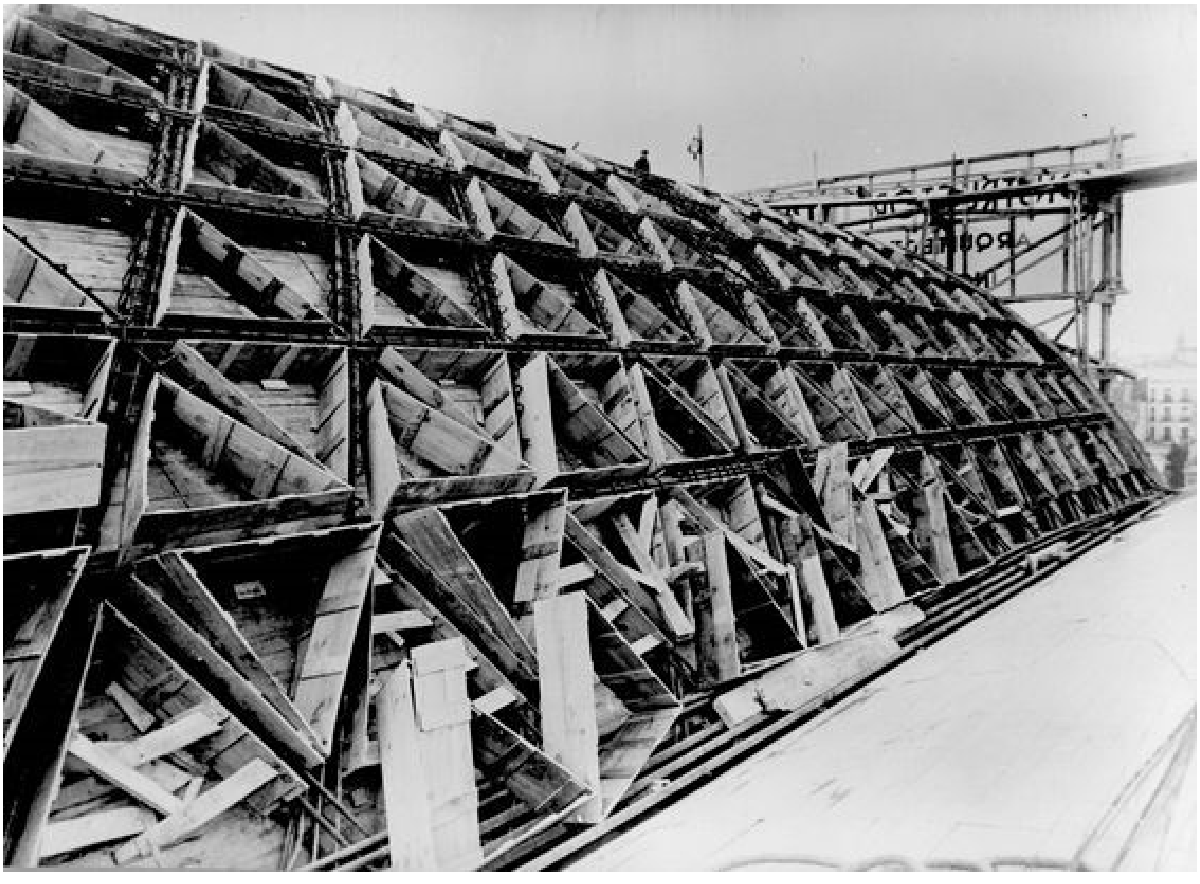

Fig. 5: Execution of the assembly and formwork of the long cylindrical shells of the Frontón Recoletos cover, Eduardo Torroja 1935, Madrid. https://www.pinterest.es/pin/302726406178912601/

3. Example case into the UAH Campus.

We will take as an example case a laminar structure of reinforced concrete built in 1943 attributed to Esteban Terradas at the military airfield of Barbera and Collar near the city of Alcalá de Henares [11]. This airfield was operative between 1934 and 1951 and then the land was ceded to the University of Alcalá together with the old facilities of Cardinal Cisneros in the center of the city to reinstall the University of Alcalá de Henares in 1977. The hangars are an installation formed by three naves of 157 meters in length and 32 meters in width, closed at both ends by prismatic structures. The central nave, covered by a long cylindrical layer of reinforced concrete, 13 meters high; the two sides, also covered with concrete, hanging cantilevered from the central structure, 9 meters high. In the original project, it was part of a group of six linear hangars, as an extension of the four rectangular hangars next to the runway (fig. 6).

Fig. 6: Current status of hangars.

3.1 Historical Evolution

This structure was never completed or used due to the early closure of the aerodrome, remaining in the state that remained until today. There have been several attempts to use this majestic structure for the use of the University. In 1990 as Botanical Garden within the Technology Park of the Sciences of the University of Alcalá (Fig. 7), and between 1997 and 2000 with ideas for its rehabilitation as the Royal Botanical Garden Juan Carlos I (fig. 8).

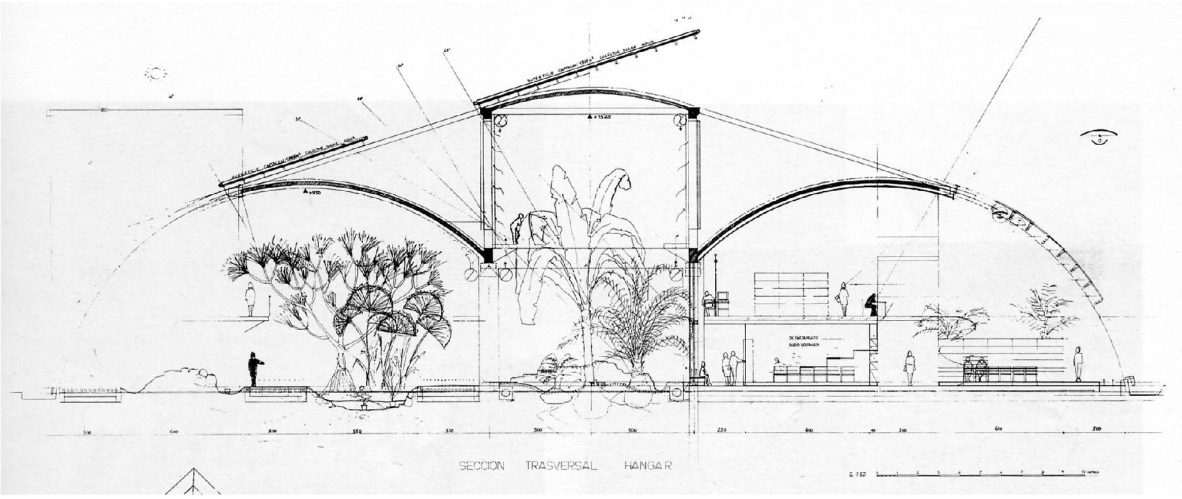

Fig. 7: Cross section of the contest to turn the hangars into a large greenhouse at the University of Alcalá. 1990.

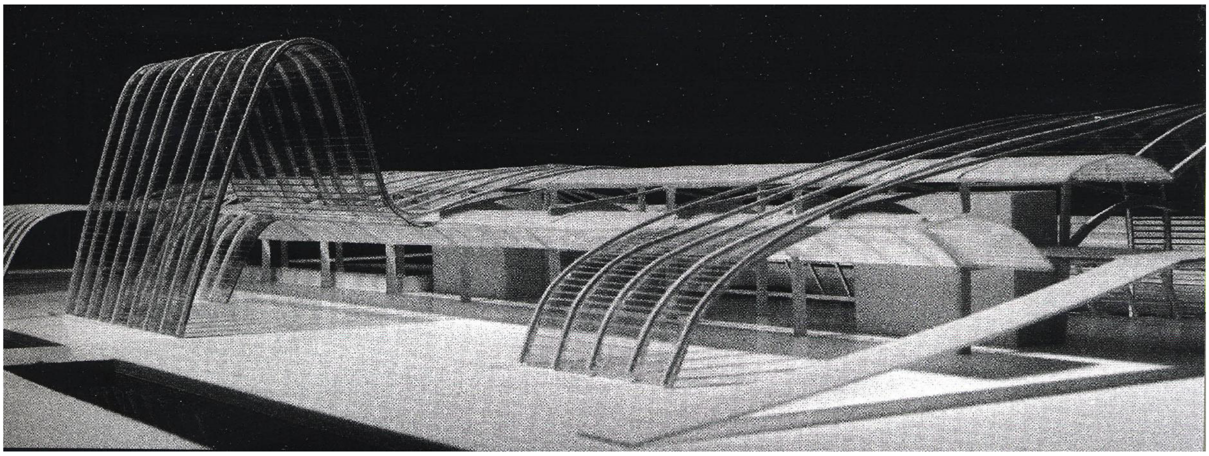

Fig. 8: View of the model of the contest to turn the hangars into a large greenhouse at the University of Alcalá. Carlos Ferrater 1997.

3.2 Actions to achieve the "immortality" of architectural heritage.

The uses of this type of structures are very varied, and the property of them also. Its state of conservation has undergone alterations more or less important, sometimes even disfiguring the building until it is almost unrecognizable. Through the analysis of the state of this type of constructions, we have seen how they have been altered, and in very few cases they have been preserved as they were designed by their author. Special mention deserve those that have been demolished, especially for speculative reasons.

This lack of protection to the contemporary architectural heritage, inheritor of the historical heritage, on the part of the competent authorities leads us to propose two lines of action: Protection and / or exhaustive documentation.

With regard to the protection of heritage, it would be advisable to follow the indications of the Charter of Krakow, "Principles for the conservation and restoration of the built heritage", of the year 2000, where it states that the measures to guarantee the protection and conservation of the built heritage are more effective if joint legal and administrative actions are carried out. In the case of Spain, it would therefore be advisable to reduce the procedures for the inclusion of these buildings in the lists of BIP (Assets of Patrimonial Interest-Bienes de interes Patrimonial) and of the BIC (Assets of Cultural Interest-Bienes de interes Cultural) drawn up by the Autonomous Communities and subsequently used by the City councils for the realization of their Catalogs of Protected Buildings. In this process should also intervene the institutions that work to regulate the work of architects, such as the Superior Council of Architects of Spain and the Official Associations of Architects of each territorial demarcation, acting as catalysts and collaborators. The work of the Colleges would be much more useful if the City Councils were also obliged to protect those buildings included in the Architecture Guides they publish, with criteria far removed from the speculative approaches that Urban Planning Regulations often allow.

Taking advantage of the existence within the Unversidad de Alcalá of the structure of the hangars, we proceeded to compile the existing information both in the Military Archive and in the archive of the University. Later, the model was built virtually using the 3D scanner and photo restoration programs, such as the photoscan pro. With all this we have obtained a real model, at scale, in which all the characteristics and all the pathologies that currently attribute the structure are reflected. With this virtual model, we have built, with the collaboration of the Laboratory Technician of the Department of Architecture, Mr. Álvaro Mozas, a module of those that make up the structure and we can see how it works (Fig. 9).

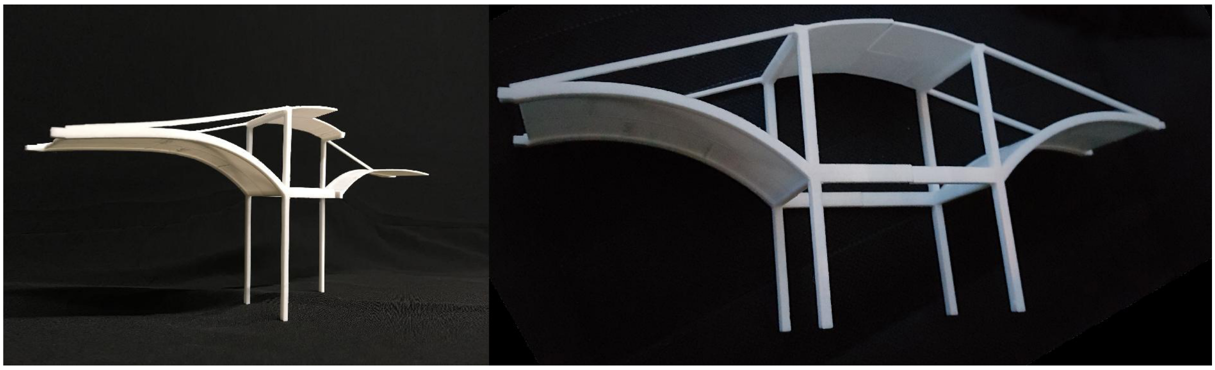

Fig. 9: Construction of a 3D model using a laser printer based on 3D construction using the LASER laser scanner

4. Conclusions

In relation to the exhaustive documentation that must be available of each building to be protected, we must return to the 19th century mentality where the revolts of the ruined places proliferated [12] to document and safeguard the inherited memory. In the same way, the new tools should be used at the service of the architect, through the use of the 3D scanner applied to those buildings considered of interest to, at least, preserve their image in a database and be used in case of deterioration or loss, or as an object of dissemination. One of the most important and relatively inexpensive tools to know and preserve heritage is based on any of its forms. [13]
This type of initiative has been developed under the auspices of private foundations (CYARK 500) whose objective is to guarantee that in a period of approximately 5 years, at least 500 elements declared World Heritage will be digitally documented in 3D. This and other similar initiatives would have maximum diffusion through prestigious international congresses (CYARK, CIPA, ISPRS, La Vie dei Mercanti), and its purpose is to serve for the study, dissemination and, above all, proceed with a hypothetical reconstruction in the case of accidental or intentional damage or loss. The goal of everything is to know how to preserve our rich architectural heritage for future generations, especially the most recent and at the same time most unprotected.
100 years after its creation, we see how legal protection has not been granted to these buildings to consider them part of the heritage. We are witnessing a process of disappearance of most of the structures that showed the way of an important period of modern architecture.
From this research, we make an inventory of the main structures made with these techniques and their current state of conservation. All this work will allow us to establish the possible measures for its possible rehabilitation, and the real or virtual reconstruction through the use of digital tools, 3D scanners or photographic studio, and especially its inclusion in the catalogs of buildings that are part of the architecture and heritage cultural at a national and international level.
The process will culminate with the possible construction on a real scale of buildings lost by digital manufacturing systems or the dissemination of their data through the augmented reality technique.

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