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The Establishment of a New Technique**

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## An Introduction to ATINER's Conference Paper Series

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Athens Institute for Education and Research

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## **Reinforced Concrete in Anastylis: The Establishment of a New Technique**

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### **Abstract**

The new technique of reinforced concrete had revolutionized during the 20th century the entire practice of construction. The new approach had consequences also on the restoration of monuments, especially from the Thirties when reinforced concrete had a widespread diffusion after the approval at the Conference of Athens. The new technique could confer to historic buildings new and greater performances compared to traditional materials like masonry and timber.

The paper wants to focus in particular on archaeological heritage, to identify what have been the reasons of the achievement of reinforced concrete for restoration.

The possibilities offered by the new technique to satisfy the specific requirements of restoration in archaeological area will be considered, reporting to its technical and structural properties in the context of archaeological remains that had lost structural completeness.

Also to the goals of the restorations for the image of the ancient ruins will be considered.

To develop this issue the work will refer to the restorations carried out between the end of World War I and the Fifties in some important archaeological areas in Italy and in Greece by Italian archaeological missions, both with references to historical sources and to observation of constructions.

These intervention practices transformed the archaeological heritage; the transformations occurred propose nowadays different issues for preservation, related to the actual consistency of the ruins.

The ancient remains with the strengthening interventions have to be considered nowadays as mixed structures. Their structural behaviour is not deep known. Deepen the knowledge of them is the first step to define maintenance programs and prevent seismic risk.

**Keywords:** mixed structures, anastylis, reinforced concrete.

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The diffusion of the new technique of reinforced concrete had a widespread diffusion from the first years of the 20th century changing the way of thinking to constructions. The empiric practice that characterized building yard from the ancient past was substituted by the importance of calculations of structures, the role of engineers grew in importance and the new materials produced big changes in design, building practice, manpower.

This new period had obviously consequences also on the restoration of monuments since reinforced concrete could confer to the structural behaviour of historic buildings, made of masonry and timber, new and greater performances and also solve many problems related to interventions.

The use of the new material involved also the restoration in archaeological areas since the beginning of the 20<sup>th</sup> century, as can be evidenced by the emblematic cases of the interventions of N.Balanos at the Acropolis of Athens and A.Evans at the Palace of *Knossos* in Crete.

The establishment of the new technique on the international context arrived with the Conference of Athens for the conservation of monuments of 1931; in that occasion some specific contributions were dedicated to the new materials for restoration.

Reinforced concrete was accepted and praised for some properties like cheapness, plasticity, possibility to give to historic constructions shear and bend resistance and to improve their performances in compression; it was also praised for its resistance to fire and durability. In fact an infinite durability was usually attributed to the new material<sup>1</sup>.

With particular reference to the Italian context, the use of the new material was accepted and applications on monuments began, also there, from the first years of the century.

In Italy an incentive to the use of reinforced concrete arrived after the devastating earthquake of *Messina-Reggio Calabria* in 1908. After that catastrophic event, the first experimentations for aseismic houses were made and reinforced concrete was established as an emergent technique, also for the reconstructions of historic buildings.

From this background, it is simpler to understand why in the Thirties the Italian attendees at the Conference of Athens supported the use of reinforced concrete. Gustavo Giovannoni<sup>2</sup>, who was representing the Italian Ministry of National Education<sup>3</sup>, underlined clearly that new materials were approved for restorations but they were assumed as means.

Reinforced concrete was used as an instrument for strengthening interventions but was not accepted aesthetically. Interventions had to be hidden

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<sup>1</sup>Especially architect Pierre Paquet, general Inspector of historic monuments in France, was a strong supporter of the use of reinforced concrete and presented many cases of restorations with use of reinforced concrete realized in French Cathedrals.

<sup>2</sup>Gustavo Giovannoni (1873-1947) is one of the main personalities in the culture of conservation of monuments in Italy in the 20th century. Architect, engineer, historian, exponent of 'scientific restoration', was also promoter of the first university of architecture in Italy.

<sup>3</sup>At that time the Ministry of Education also carried out the tasks of the Ministry of Culture.

inside the structures or dissimulated, by adding to the mixture coloured pigments or particular aggregates to be similar to stone, or they had to be covered with plaster<sup>1</sup>. These precepts were reported also in the Athens Charter.

Other Italian architects, engineers and archaeologists that had worked in archaeological areas in the decades before, presented some cases of interventions in archaeological areas where reinforced concrete had been experimented<sup>2</sup>.

One of the first cases realized is that of anastylosis of the temple C at *Selinunte* (1925-1926), directed by F.Valenti, the Superintendent of medieval and modern art in Sicily<sup>3</sup>. In that work they put iron beams inside the architraves, they used metal and reinforced concrete clamps to strengthen the cracked capitals and they integrated some capitals that presented exfoliation with reinforced concrete. In that case reinforced concrete was covered with a mixture to reproduce tuff for “aesthetic reasons”.

After the Conference, the official admission of the new technique contributed to its diffusion in a lot of interventions in the archaeological areas in Italy and in the occupied territories, like Lybia and Dodecanese.

It is possible to identify some properties of reinforced concrete that fit with the specific requirements of interventions in archaeological areas and specifically with the interventions of anastylosis<sup>4</sup>.

First it is relevant also that restorations in far regions, frequently in remote places without many facilities, were carried out with local unqualified manpower. Reinforced concrete structures were simpler to realize and, except from providing iron bars, the technique answered well to these conditions.

Referring again to the contributions of the Conference that deal with the preservation of archaeological areas and to other texts of the same period, it is possible to understand the main way of perceiving the archaeological heritage, called in terms of “ruins”.

Monuments of the ancient past were perceived like distant memories belonging to disappeared civilizations. There was a kind of respect for their image of incomplete constructions and that aspect had to be conserved, together with the scientific and didactic goals of the anastylosis, gradually opened to a wider public.

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<sup>1</sup>In the case of the restoration of Parthenon, Balanos used reinforced concrete in some visible elements. During the debates that followed the works, it was recognized that with this choice the new parts were recognizable, but the aesthetic effect wasn't appreciated.

<sup>2</sup>An interesting contribution was that of L.Pernier, the director of the Italian Archaeological School in Athens and of the excavations of *Festos*. He explained the different goals of the interventions in *Festos* and that made by Evans in *Knossos*. In the first case the work was limited to a restoration of ancient remains and only few covering of reinforced concrete were built to protect the ruins. At *Konssos* the reconstructions of the ancient Palace made with reinforced concrete were extended and also determined discussion in the scientific context.

<sup>3</sup>In his other contribution at the Conference, Valenti presented the restorations of Medieval monuments in Sicily with significant use of reinforced concrete, carried out after the earthquake of 1908.

<sup>4</sup>With the term “anastylosis” we refer to the intervention that in presence of an adequate number of pieces of the ancient building, after specific studies and surveys, attend to their recomposition in their original position.

So a particular attention was dedicated to the aesthetic effect of the interventions. This is always a component of a restoration project, but for interventions in archaeological area it seems to be predominant. The conservation of the image of ancient remains was also reached with the design of the near vegetation. In these terms it can be understood further that the interventions made with reinforced concrete couldn't have been revealed in that image of the ancient monuments.

The new technique with its high resistance in reduced dimensions permitted to strengthen the structures by inserting, for example, reinforced concrete beams inside the section of architraves and columns. So reinforced structures were invisible, or at least they could have been covered.

The anastylosis of ancient monuments increased between the two World Wars, when in Italy there were on one side the emerging of the touristic fruition of archaeological areas and on the other one the instrumentalization of Roman and Greek antiquities by the fascist government.

We find reinforced concrete interventions hidden inside the structures for example in the anastylosis of the *Capitolium* of *Brescia* (worked directed by architect Ballerio, 1939-1945). In this case the original drums of marble were cut inside to put the iron bars and pour the concrete; also the missing parts of the columns were made with reinforced concrete and were covered with bricks. The architrave was realized with bricks and an inner part of reinforced concrete. In the upper part the tympanum was made of bricks and the cornices were made of reinforced concrete covered with mortar.

Similar interventions were realized in many archaeological areas of the Dodecanese at the end of the Thirties by the offices of Italian superintendents, during the government of De Vecchi.

At the Acropolis of Rhodes in 1938-1940 archaeologist L. Laurenzi and architect M. Paolini directed the anastylosis of the temple of Apollo Pitheus. Only few elements of the ancient temple were conserved. They built new drums and capitals with stone and cut them in the central section to put a pillar of reinforced concrete. Also the ancient drums and the capital conserved were cut in the same way and strengthened. The trabeation was built with reinforced concrete and the few ancient blocks were held up by it.

Similar interventions were realized in the same period at the Acropolis of *Camiros* and at the Acropolis of *Lindos*. Also on the island of Kos we find anastylosis of ancient monuments realized with the same techniques. One of the more extended was that of West *Gymnasium* in Kos town.

This kind of interventions were of course very invasive. A lot of ancient material was lost to insert the new parts of reinforced concrete and the traces of ancient works on the blocks were lost forever.

Looking at these practices today we can acknowledge the great enthusiasm and faith of the period for the new materials but also the way of considering the conservation of the ancient remains related more to their image than to their material consistence.



Furthermore time has demonstrated that the durability attributed to the new material was not infinite. The oxidation of iron bars involved the ancient structures and decay occurred since few decades.

Some aspects due to the technique and the difficulties of construction had incidence on decay. For example it was difficult to control the thickness of concrete cover of the beams poured inside structures and today we can see that it was very thin, for example at the *Gymnasium* of Kos. This kind of interventions probably had also some problems with the segregation of aggregates.

Furthermore it is also possible to see in the constructions damaged that the aggregate has medium and big dimension (4-6 cm), for examples at the Acropolis of Camiros, so the presence of void in concrete was probably quite high. We also have to consider that the archaeological remains are usually directly exposed to rains and marine wind.

Other factors like the chemical and physical compatibility between concrete and different kind of stones have to be considered; for example the characteristics of local porous stone of the monuments of Rhodes accelerated the decay process in presence of reinforced concrete interventions. In fact the ancient remains strengthened with reinforced concrete in Rhodes are interested by different degrees of decay, that has caused in some cases the collapse or the removal of modern interventions<sup>1</sup>.

The combination of all these factors influences the process of decay.

Another relevant theme related to the interventions of anastylosis, that comes out clearly from the text of the archaeologists of the first part of the 20th century, is the importance of the scientific method to assure the correct repositioning of the different elements of the ancient building.

At the Conference P.Leòn, director of fine arts in France, underlined that the use of new techniques allowed to avoid disassembly and reassembly of the monuments. Those operations were defined dangerous and arbitrary, because could cause the loss of ancient elements.

In relation with this aspect we can find another quality of the new technique that is the possibility, in some cases, to be installed without disassembling the monument.

In some archaeological sites in Sicily there were cases of strengthening interventions installed without disassembling the ancient structures at the beginning of the Forties.

The doric temple of Olympic Zeus, distant about 3 km from the city of *Siracusa*, was damaged by a lightning in 1939. The two columns of the temple conserved were deep cracked.

In the interventions directed by G.Cultrera only the little fragments of marble that were falling were removed and the drums were bandaged. Then thin vertical canals were excavated for all the height of the columns. Also

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<sup>1</sup>The first is the case of the Great *Stoà* at the Acropolis of *Camiros* that collapsed in the Sixties. The second is that of the restoration directed by the Greek Ministry of Culture at the Acropolis of *Lindos* since 1985.

horizontal canals were excavated. Thin metal bars were put inside the canals and cement was poured inside the same holes.

Another intervention realized without the disassembling of the ancient remains was in the old center of *Siracusa* for the liberation of the columns of *Artemision* (1942). The two columns of the temple were cracked and connected with an old house. The fragmented parts were connected with claws, the columns were armed externally with iron bars and then cement was poured for the reintegration. With this strengthening intervention the house was demolished and the columns liberated. Also one capital was completed with reinforced concrete.

There is another property of reinforced concrete that answers well to the requirements of the particular conditions of anastylosis of ancient structures.

It is the plasticity, characteristic of poured materials. Since concrete is poured in the building yard it can adapt to the different dimensions and conformations of the ancient ruins, that change from case to case.

A significant example of this property is given by the anastylosis of Temple E in *Selinunte* (1956-1959), directed by archaeologist I. Bovio Marconi with the help of architects and engineers. Reinforced concrete elements were realized to complete the architraves. Since every block of architrave was different from the other, the integrations were poured to fit with the surfaces of each ancient element and were connected. Also integrations of capitals were poured with reinforced concrete that could adapt to the particular shape of each element.

The plasticity of the material also permitted to realize the architectural particulars modelling the grade of definition. In the case of temple E ancient flutes were eroded and smoothed. So the new flutes made with concrete were modelled to be smoothed too in order to reduce the contrast with the ancient.

All this kind of operations are of course less complicated and expansive than cutting similar pieces with stone. Also in this case the new parts were covered with a mixture to look like the stone of the temple.

I. Bovio Marconi explained in a text published in 1967 the methodologies and the choices adopted for the anastylosis of temple E. We read that also the hypothesis with reinforced concrete beams inside columns and architraves had been evaluated. That was the only solution safe in case of strong earthquake.

But earthquake was not the certain cause of the collapse of the temple and that kind of interventions were judged extraneous and invasive. So the decision was to realize more conservative interventions, limiting the project to static goals.

It is possible to read a sort of continuity of the use of reinforced concrete for interventions of anastylosis made by Italian through the 20th century.

That demonstrates that once the convenience offered by the technique was acknowledged and experimented it has been repeated with modest changes. These changes were related to the volunteer to reduce the impact of the intervention and the loss of ancient material, related to a deeper consciousness of the objectives of conservation.

The evolution of this context of restorations in the 20th century had many consequences on the archaeological heritage.

The built heritage we have to face today has to be considered like a palimpsest: after the previous historic transformations, the enthusiasm for modern techniques for restorations during the 20<sup>th</sup> century increased the complexity of monuments.

The interventions made with reinforced concrete, so different from historic materials, changed the structural behaviour of the ancient remains.

This is particularly relevant in the cases of anastylosis, where the overall image of the ruin was kept but it doesn't absolutely match with the real structural behaviour of the construction.

In ancient structures, especially in ancient Greek monuments made with perfectly cut stones, the stability was related to friction between blocks, weight and presence of metal connections.

For example, referring to the practice of inserting a reinforced concrete pillar inside the section of the columns, it completely changed their structural scheme. The stability depends from other factors, as the hinge joint at the base and at the top of the columns, the connections between the pillar and the drums and the possible state of decay of the new and ancient parts.

The complexity increased in terms of constructive characteristics; first reinforced concrete changed masses and structural hinge joints. Then, as outlined before, the durability of interventions is reduced by constructive procedures and nature of stones, and decay affects the constructive characteristics of ancient remains during time. Finally there are problems with the different resistance and expansions of the materials.

In order to understand the real consistence of the monuments, a sort of stratigraphy of the interventions has to be considered till recent years.

So there are lots of factors that we have to study to understand what is the structural behaviour of the ancient remains today.

This is very important to guarantee structural safety, to evaluate seismic vulnerability and to program prevention, particularly in nations like Italy, Greece and Turkey where the richness of archaeological areas coexist with an high seismic risk. At the moment in Italy some specific guidelines for the preservation of archaeological areas note the importance to study the modern interventions, but don't deepen the issue in the specific.

Also in static conditions this transformed heritage proposes many issues.

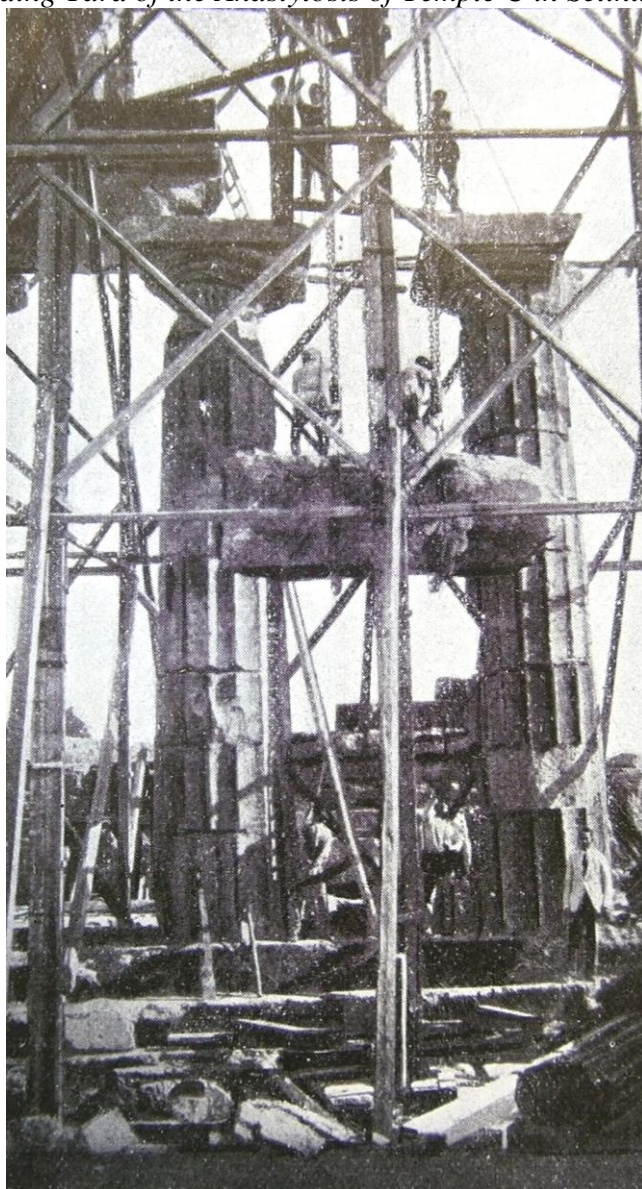
For the preservation of monuments we know that is more important to make maintenance interventions than restoration, both for the conservation of the building and for economic reasons.

So the first step for the preservation of archaeological remains is to plan maintenance programs that consider the specific request of reinforced concrete interventions. So it is necessary to improve the knowledge of them, their interaction with the ancient parts, and modes and times of decay.

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**Figure 1.** *Building Yard of the Anastylis of Temple C in Selinunte*



**Figure 2.** *Capitolium of Brescia. It is possible to see the reinforced concrete beam on the left of the architrave*



**Figure 3.** *Temple of Apollo Pitheus in Rhodes*



**Figure 4.** *West Gymnasium in Kos*



**Figure 5.** *Artemision of Siracusa. Historical photos before and after the intervention*



Fig. 9. SIRACUSA: Artemision. Le colonne prima del restauro.



Fig. 10. SIRACUSA: Artemision. Le colonne dopo il restauro.

**Figure 6.** Drawings for the integrations of reinforced concrete for the architraves of temple E in Selinunte

