Sustainability and environmental care in the anastylosis and restoration project of the first order of the Severian marble scaenaefrons of the theater of Hierapolis of Phrygia

PROCEEDINGS

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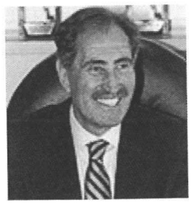

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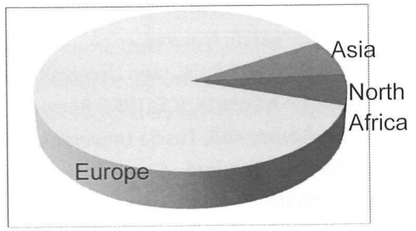

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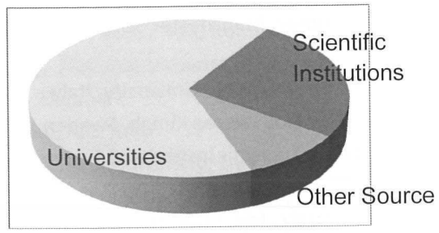

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SUSTAINABILITY AND ENVIRONMENTAL CARE IN THE ANASTYLOSIS AND RESTORATION PROJECT OF THE FIRST ORDER OF THE SEVERIAN MARBLE *SCAENAEFRONS* OF THE THEATER OF HIERAPOLIS OF PHRYGIA

Mighetto Paolo[1]

[1]Italian Archaeological Mission at Hierapolis of Phrygia, Italy-Turkey, acmarch@yahoo.com

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ABSTRACT

Times are now ready to provide the necessary focus on the environment in which we live and even the world of restoration and conservation can now finally play its part to preserve the world in which we live for future generations promoting a sustainable conservation that can transmit the cultural heritage without intolerable sacrifices for the environment.

INTRODUCTION

Attention to the environment has become an unavoidable and inescapable requirement; in the construction, that is an urgent need according that the buildings and the built environment is using half of the material extracted from the earth's crust and produce each year more than 450 million tons of construction and demolition waste, more than a quarter of all the waste products in the world.

Sustainability and environmental compliance are almost universally shared and in the new building the application of these concepts is largely encoded by protocols and certifications such as LEED or Klimahause. Unfortunately, in restoration and conservation this is still in its early and too many times, hiding behind the practice and old habits, we use solutions that are not environmental friendly and, moreover, extremely expensive if you consider, in addition to the capital cost of materials, environmental and social expenses related to production, use and disposal of these same materials no longer consistent with our development.

To encourage the use of natural products rather than synthetically originated is therefore today a necessity; not only regarding a more sustainable exploitation of natural resources, but also and above all, to limit the production of synthetic materials, responsible for the increasing emissions in atmosphere and in the environment of harmful products. We should not forget that the disposal and the dispersal of those products, even considering that –despite the long time of a potential reversibility of the intervention- sooner or later we will have to replace protections, reinstatement, reinforces, and having put the problem of their own, very difficult and expensive disposal in nature. Even all these may be good reasons to increase testing and use of natural products in all proceedings related to the conservation of cultural heritage, but, if still not enough, consider that the natural products are the most compatible with the ancient materials - because they are the same materials- and less subject to alteration or degradation phenomena that, over time, may even involve the same original material contradicting the root instances that were the basis of conservative operations. Unfortunately, with regard to ancient materials, the rejection is never as fast as the human body and some times the damages can reveal after years or even decades, however, after a long time, and maybe after the induced degradation has been developed and has progressed from the inside, hidden and invisible, like a cancer.

The primary intent of a restoration should be those of conservation but, certainly, not apart from the effects they may cause on the surrounding environment; whether producing the materials that can save an architectural work from decay contributes to increase the production of greenhouse gases -the primarily responsible for pollution which is one of the most active in the deterioration of the same ancient works-, then the result of the operation leads into an irrational spiral.

In such way, this could be good in a short-term , but looking further it will reveal completely bad for the same heritage and for its preservation.
Too often in the past, solutions apparently suitable to the needs of protection, after decades, are proved to be even harmful as not in accordance with the same original materials, as well as the environment.
Tons of concrete were used in the twentieth century to consolidate the remains of the past -let's just think at the restoration of the Acropolis in Athens made by Balanos, just as a well known example- and even if the "concrete" was used with wisdom to avoid the problem of salts -for instance, in the hyposcenium of the theater of Hierapolis', with pre-cast blocks for reinstatement of the transverse arches- remains the problem, in future, necessary, replacement of cement additions, where and how to dispose of these materials, however, in a yard "little technological" as is a restoration yard.
Having said this, let me now explain the project for the theater of Hierapolis through the objectives, policies and technical choices that led the accomplishment.
The working plan for the anastylosis of the first order of Severian scaenaefrons of the theater of Hierapolis was completed in January 2009 after which, on the basis of the preliminary design drawn up by the Italian Archaeological Mission, the Turkish government decided to finance the works in summer 2008, with a budget of one million euros (2.440.400 Turkish lira). After a further review by the Italian Mission, the project was sent to the Turkish Ministerial Committee for Cultural Heritage on May 27, 2009 and was approved by the 12 of June of the same year. At The making of the various phases of the project has worked a wide team of architects, engineers and historians led by the writer (engineer Franco Galvagno, architects Filippo Masino and Giorgio Sobrà, archaeologist Caterina Polito, architects Alessandra Aires and Marco Minari for the environmental and safety aspects related to construction site).
The theater of Hierapolis appears today as the result of an ongoing historical process that led to the gradual transformation of the ancient theater -already with different and complex phases of construction and restoration that are still under investigation- to a collapsed building for the storage of grain, poor houses and stables subsequent to the earthquake of the seventh century AD, that left in ruins and occasionally inhabited by nomadic peoples (a particularly long period, at least from the eleventh to twentieth century), submitted to archaeological excavation and restoration (activities of the Italian Mission has focused on the theater since 1957), and then again to cultural heritage under protection and visited every year by nearly two million tourists from all over the world.
The theater is a monumental complex that can only be considered in its complete history, its stages of transformation more or less significant in the various functions it has assumed, in the progressive and uninterrupted layering of events that led to its present appearance. After the excavation and restoration works done by the Mission, the theater is now turning into a veritable museum of itself and its history, in the words of Professor Francesco D'Andria, Director of the Italian Archaeological Mission, "*the theater of Hierapolis is now a theater-museum that presents itself to visitors as a great book on open air architecture*".
For the old building it is now evolving a phase of increasing transformation into a museum that began with the archaeological discovery and now requires – according to tourism needs to rule and stream within the bounds of sustainability and compatibility against the property to be protected- further restoration and reconstruction, which shall remain on the path of those already implemented in the last forty years.
This is a true "super-project" that, through the emptying of the cavea and orchaestra caused by the collapse (during the Fifties and Eighties), the anastylosis of the hyposcenium (1982-'85 and 2004-'07), the restoration of the transverse arches of the stage (1978-'82), the replacement of the back wall until the level of the first cornice (1992-'94), the restoration of the *imacavea* with the replacement of staircases access (1995-'99 and 2003), the reassembly of the stage (2005-'07) and, of course, the continuation of the excavations, today reaches the goal of the anastylosis of the first order of the Severian marble *scaenaefrons* as the engine for consequent conversion of

the stage building as a museum, in the full meaning of (the verb) to restore: restore architectural significance to the degraded manufactured building.
The excavations that freed the orchestra and imacavea from the collapsed material (and deposit) accumulated over the centuries of neglect, resulted in the identification and cataloging the thousands of pieces that made up the marble decoration of the scene (about 400 original blocks, but now further crushed, make the first order). The process of knowledge, has now reached very advanced stages, then allowed to achieve a very fine mapping of each parts and their mutual relations, the basis of the reconstruction hypothesis.
The reorganization of the marble elements and their cataloging then made it possible to reorganize the square behind the theater and to complete the on ground reassembly of the friezes and cornices of the order (as well as one of the gables and the sequence of columns and capitals) to allow easy reading, to assess their condition and achieve the insights required for the anastylosis project and building.
The extraordinary wealth of elements that composing the Severian marble frontescena -four thousand pieces that made up the three overlayed orders of the scene and parasceni, partly originated from the previous Flavian decoration- is now deposited, as mentioned, in the large yard behind the theater, between this, the *Insula* 104 and the Sanctuary of Apollo; the work done since 2004 by the architects of the Italian Mission Filippo Masino and Giorgio Sobrà, with the assistance of Haşım Yıldız, now allow us to analyze all elements of the first order -preserved for more than 95% of the approximately 400 original blocks- and, particularly, to read the signs of construction and workmanship, to deepen the intrinsic and extrinsic relations, to assess the state of deterioration, to speculate a conservation plan according to the current strategies for managing the site of Hierapolis-Pamukkale, a World Heritage Site since 1988 (No. 485 of the UNESCO list).
The original disordered cumulus of blocks in the outer area of the theater determined, however, over the decades, the arise of widespread alteration and degradation also respect of the surfaces that were originally hidden or protected by overhangs above. In addition to the deterioration due to the exposure of the materials, to the restoration and ancient rebuilding as well as by subsequent collapses, were added to those due to the prolonged burial phases of abandonment of the building and then those related to their rediscovery -the signs of digging and signs of their carrying outside -and finally the recent exposure to an environment certainly not positive to preservation. The site of Hierapolis-Pamukkale is in fact interested in strong temperature range in the diurnal-nocturnal cycle (also 30-40°) and the seasonal cycle (from the scorching summer sun to winter frost), as well as a strong wind with strong gusts of wind filled with sand in suspension.
The massive number of tourists, that until 2007 and for more than twenty years has led every day hundreds of buses, just a few hundred meters from the theater, has contributed to the pollution by exhausted gases to form black crusts on some blocks that are more exposed and less washed out. Differential degradation due to the different textures and consistencies of the original material resulted in loss of material located at the veins of marble, some blocks have also suffered with time, due to the incongruous position, a significant deformation with variations in shape and form. In localized cases the passage of ancient calcareous water has caused the arising of deposit and in some cases wedge thickens in the meanders of the carved surface.
One of the most important problems of those related to degradation of the elements of frontescena is doubtless represented by the loss of integrity of the column shafts. In almost all cases, the shaft appears broken into two or more parties as a result of the collapse in the orchestra. The analysis of parts has allowed to reassemble the piece and the plans identifying the corresponding faces of fracturing, almost always inclined but relatively regular. Unfortunately, that's why the restoration of the parts of the shafts will need reinforced stitching to ensure that the assembly with the onset of excessive shear strain, possibly caused by an earthquake, won't effect further degradation or partial collapses.

Owing to previous matters, and in view of the very high percentage of the original recognized and classified pieces (about 97% of the first order), the choice of operating anastylosis of the first order, and thus the critical restoration of the dismembered parts (Venice Charter, Art. 15), is justified both by preserving and protecting the same marble elements of the architectural apparatus and those relating to recreate the unit interpretation of *disiecta membra* of the theater.
If we consider, the subsequent consolidation of the wall behind the stage- already integrated in the Seventies: a single row of dry laid travertine blocks, more then six meters high, in need of structural aid in the event of an earthquake-, the possibility of increasing the knowledge on Severian and Flavian construction site -as well as *scaenaefrons* architecture and its history-, the opportunity of a further reorganization of the area behind the theater and the opening of new fronts of excavation and research in areas already occupied by the marble blocks, you can really agree with the drafters of the Charter of Athens in defining *well opus put in place the original elements found* (Charter of Athens, ch. IV).
Evaluation of the alternative hypotheses to anastylosis led to exclude the preservation of pieces on the ground in the back yard, because this solution would require the formation of a large-fenced perimeter -with significant interferences with the foundations of the uprights in the archaeological ground- and, above all, a system of coverage they need, assuming an area of approximately 3,000 square meters of extension subject to snowfall in winter and strong summer winds, would have involved the preparation of a problematic intervention –though resolvable- from the landscape point of view, neither allowing the investigation of the urban plan around the theater nor recovering the public availability of the stage.
Anastylosis planning and works related to it follow, anyway, the principles laid down by the Restoration Charters -to Athens in 1931, the Venice of 1964, and that of Krakow in 2000-, and they must also make reference to all phases of the project and construction.

- Anastylosis as recomposition of the original elements now dismembered (Athens Charter, ch. IV, Venice Charter, Art. 15);
- Using new materials always recognizable (Athens Charter, ditto);
- Wise use of all resources of modern technology (Athens Charter, ch. V) and all the most modern methods of structure and conservation, whose efficiency has been demonstrated by scientific data, and guaranteed by experience and adapted to the real needs of conservation (Venice Charter, Art. 10; Krakow Charter, ch. 10);
- Opportunities to restore the monument of the elements of sculpture and decoration which had been separated as a result of digging (paraphrase of the Venice Charter, Art. 8);
- Respect for original material and authentic documents (Venice Charter, Art. 9); any integration, recognized as essential for aesthetic and technical reasons, must bear a contemporary mark (*ibid.*) and achieved in a language that conforms with contemporary architecture (Krakow Charter, ch. 4);
- Replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence (Venice Charter, Art. 12 and Art. 15);
- The intervention should ensure compatibility with the materials, structures and existing architectural values (Krakow Charter, ch. 10);

RESULTS

The principle we've followed in making the consolidation project is based on the concept of "improvement" as *the execution of one or more works on each structural elements of the building with the aim of achieving a higher degree of security without changing the overall behavior* (Italian technical standards); essentially, with the objective of preserving the integrity of the historical artifact material aiming to consolidate the uniformity of the masses.

When using reinforced stitching for the rough elements of the order, the drilling is minimized to achieve adequate levels of security, preserving the authenticity structural; filling the spaces with compatible material, the mechanical properties consistent with the existing structure, improves the distribution of loads whilst improving the mechanical strength of the appliance and decorative walls. This will prevent the strain nucleous due to the presence of heterogeneous masses that may be responsible for spoilage phenomena such as cracking, condensation, cumbersome structure, with the inevitable incentive of the degradation.
On the other hand, the need to tie together the elements of the order that were originally laid dry with only the interposition of leaded sealed hinges it can be seen against a structure that since the dawn of its history has been subject to localized or generalized instability and crashes, also due to the impressive seismic activity of the ierapolitan area. While the anastylosis is generally considered the best method to preserve the ancient material, then this must guarantee the right balance between conservation and safety, which is also the result of a thorough consideration of the "time-testing" on the old structures, leading to an intervention that arises from the consideration of the *minimum useful intervention*, as well as recommended by the drafters of Section III of the Final Document of the International Conference on Conservation Kraków 2000 (Article IV).
Chosing the Glass Fiber Reinforced Polyester (GFRP Glass Fiber Reinforced Polymer) as the material of the reinforcing ties -used only in the form of spiral bars as a substitute for more traditional stainless steel bars- is motivated by the strength of the material in presence of high temperature, and for its excellent anti-corrosive qualities, as well as an excellent cost-performance ratio. The use of such material in the form of spiral bars also helps ensure a tight fit to the natural anchoring mortars. The reference bar is made of alkali resistant glass fiber and polyester resin, with increased bond made coated quartz sand. The sustainability characteristics that suggested this choice are the following:

- High chemical resistance with no exposure to corrosion even in harsh environments;
- High strength and, particularly, high tensile strength;
- Fully compatibility with traditional building materials;
- High temperature resistance that ensures dimensional stability even in the case of temperature fluctuations particularly high;
- High dielectric properties (stability of the structure even in the presence of high electrical stress) and non-magnetic (no formation of Faraday cages);
- No harmful emissions;
- Low environmental impact and disposal of surplus or waste materials in accordance with standard practices for municipal solid waste.

The same choice of using ties between the opposite walls of frontescena and retroscena, but with a fully contemporary language and materials -this means metal arches that reconstitute the interior volume of the scaenae building- concern the attention to the original geometry -product of the history of the building- to the specific mechanical history of the building that allow us to understand and evaluate the reliability and effectiveness of the technical solutions provided. It 'should be emphasized that the new consolidation facilities and related staires will ensure the chance for a maintenance over time in the structure and to those parts of the building that are now inaccessible.
For anastylosis collateral metal structures (scaffold binding between the walls of scaenae building and stairs of service) the choice of material has ended up to COR-TEN steel. This type of steel is now widespread and firmly established in almost all countries, not least for its aesthetic features but also for its two main distinguishing features:

- (*CORrosion resistance*);
- (*TENsile strength*).

The use of COR-TEN as a substitute for common structural carbon steels can achieve appreciable reductions in thickness and consequent reductions in weight; the excellent resistance of the COR-TEN to atmospheric corrosion, allow to use it in its natural state, significantly reducing the periodic maintenance. The COR-TEN steel, when exposed to different atmospheric conditions, becomes covered with an uniform and durable coating of brown coloring -oxides formed by its alloying elements- which prevents the progressive spread of corrosion. The refined aesthetic as offered by the natural color and surface texture of the COR-TEN increases its value and suggested the choice for such an important building as the theater of Hierapolis.
The eco-efficiency of the material is demonstrated by its cycle, so to speak, "from cradle to cradle" for which, at the time of the reversibility of the intervention you can get all the artifacts intact and completely reusable, suitable to be reused elsewhere or to be conferred in steel consumption returning the entire amount of material removed from the ecosystem at the time of construction.
When using materials for restoration, consolidation and reintegration, natural materials were privileged excluding, with referring to the bedding and consolidation mortar, all those of synthetic production, such as resins or cement.
While in the past years, the natural materials would not allow to solve all the structural problems related to conservation, the development of technological research related to the selection and preparation of mixtures of natural hydraulic limes allow us now to have completely eco-friendly products that reach classes of resistance comparable to synthetic products and, for mortars, even the M15 class, according to European standard EN 998-2.
However the final choice of materials and their components must be the result of careful sampling of different original materials whose laboratory analysis will determine the exact compositions and dosages of the new materials to be used;
A careful analysis of markets and in-depth studies on interventions already implemented and tested in the international arena allowed us to identify and focus on some products for the bedding, the consolidation and anchoring, based on natural hydraulic lime, cement-free, low or very low salt content water-soluble.
Such products, of current production and easily available on the market, are obtained by cooking clayey limestone at low temperatures, particularly natural marl. The mineralogical main constituent is bi-ß calcium silicate that, reacting with the mixing water, develops hydrates stable compounds that can be conferred to the mortar mechanical properties and elasticity that ensure durability; by their nature, these are not mineral reactive in presence of sulfate that may be contained in the original materials and, above all, they are free of tricalcium silicate and tricalcium aluminate, the typical constituents of Portland cement.
Without prejudice to the characteristics of the original materials and considering the futility of adopting new materials excessively stronger than those for the bedding of the travertine blocks of the back wall of the stage and parts of marble elements of repositioning, we will use a natural hydraulic lime NHL 5 to ensure the mechanical strength after 28 days, greater than 5 N / mm.
Considering that the mechanical properties of any mortar depend on many factors -both environmental temperature, humidity, time of ripening- related both to the packaging of the dough, as the dosage of binder, the amount of water in mix, the type of aggregate.
The kind of aggregate, the ratio of binder and inert, the relationship between water and binder are the necessary information to be discussed about the basic mechanical properties of any mortar; demonstrating how it is considered that given the strength of late maturation of the mortar can increase by about 30 to 40% using an inert selected maximum particle size of 5 mm instead of 2 mm, and up to 60% using an inert selected maximum particle size of 15 mm instead of 2 mm.

To restore the continuity of the structural parts and the broken marble elements, the consolidation injections of hydraulic lime can provide 28-day compressive strength of 9 N/mm and a resistance to bending, always after 28 days of ripening, of 3 N/mm, with a secant elasticity modulus approximately of 9,000 N/mm.
There are even high-strength structural grout, available that are always composed of natural hydraulic lime NHL 5 and selected aggregates, which may very well replace the shrinkage compensated cement mortar in fixing reinforcement of metal structures of the stage, ensuring strength classes M15 with a compressive strength at the end of maturity greater than 18 N/mm.

CONCLUSIONS

Using only structural grout of natural hydraulic lime for bedding and consolidation represents a significant breakthrough in the international outline of conservation and a steady choice in terms of environmental compatibility and sustainability.
We applied the principles of environmental sustainability in the field of restoration in a complex project involving one of the most important monuments of Turkey.
In conclusion, times are now ready to provide the necessary focus on the environment in which we live and even the world of restoration and conservation can now finally play its part to preserve the world in which we live for future generations promoting a sustainable conservation that can transmit the cultural heritage without intolerable sacrifices for the environment.

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Teamwork and the high specialization distinguish the work of the Italian Mission; with over 50 years of work at the site of Hierapolis-Pamukkale the Italian Mission is now one of the main centers of archaeological research, conservation and preservation in Turkey.
Credits of the project:
Missione Archeologica Italiana a Hierapolis di Frigia, prof. Francesco D'Andria (client)
Arch. Paolo Mighetto (project and coordination), eng. Franco Galvagno (structure), arch. Filippo Masino arch. Giorgio Sobrà (historical analysis and reconstruction of the *scaenaefrons*), dr. Caterina Polito (archaeologist), arch. Alessandra Aires (landscape setting), arch. Marco Minari (safety analysis), arch. Andrea Sillano (project collaborator), arch. Salvatore Bartoletta (structure collaborator), arch. Massimiliano Limoncelli arch. Silvia Freccero (rendering).

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FIGURES

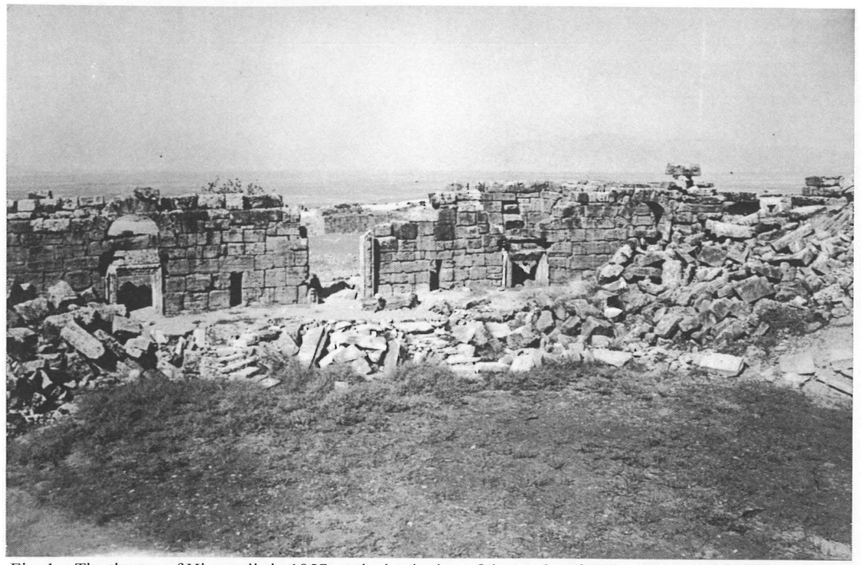

Fig. 1 – The theatre of Hierapolis in 1957, at the beginning of the works of Italian Mission (MAIER Archives)

Fig. 2 – The theatre of Hierapolis in 2007, after the restoration of the stage and the hyposcaenium. Behind the theatre, the square of the reconstructions (Paolo Mighetto)

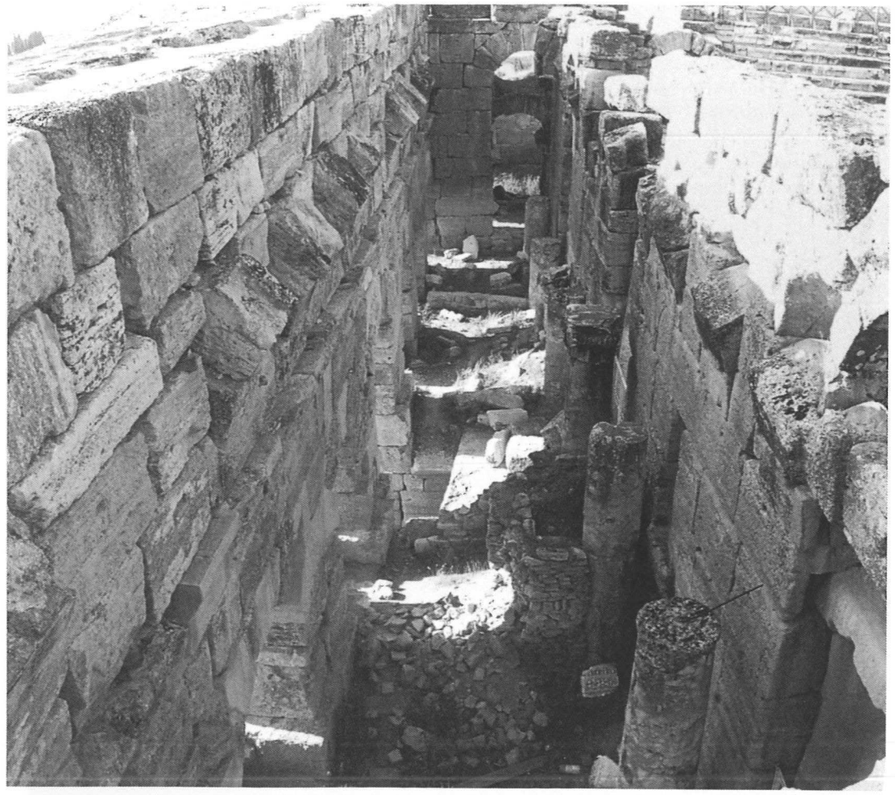

Fig. 3 – The *scaenae* building of the theatre with the sets of transverse arches (Paolo Mighetto)

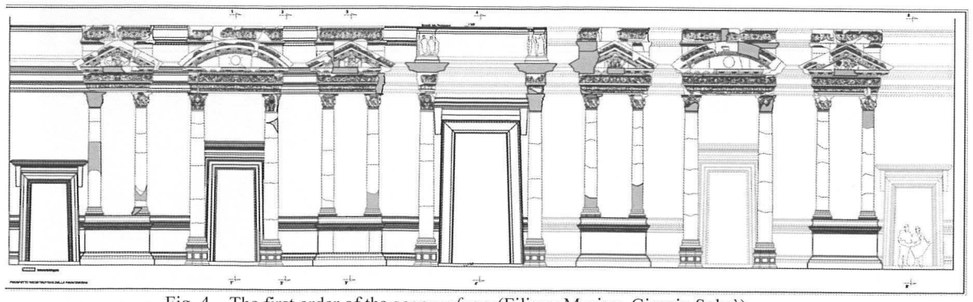

Fig. 4 – The first order of the *scaenaefrons* (Filippo Masino, Giorgio Sobrà)

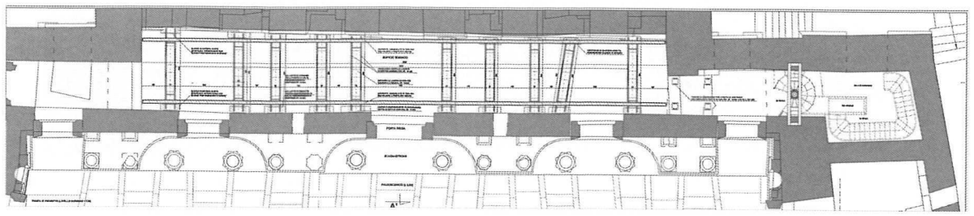

Fig. 5 – Plan of the stage after the interventions (Paolo Mighetto)

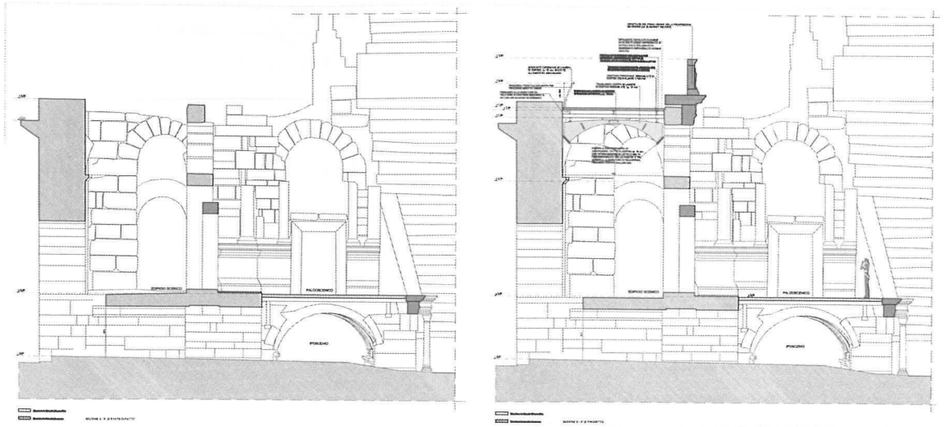

Fig. 6 – Transversal section on the *scaenae* building before and after the interventions (Paolo Mighetto)

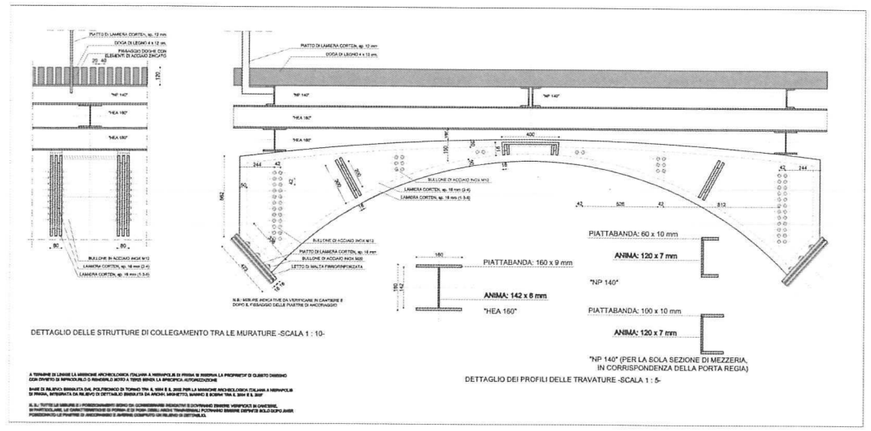

Fig. 7 – Inner-outer *scaenae* building walls connection system (Paolo Mighetto, Franco Galvagno)