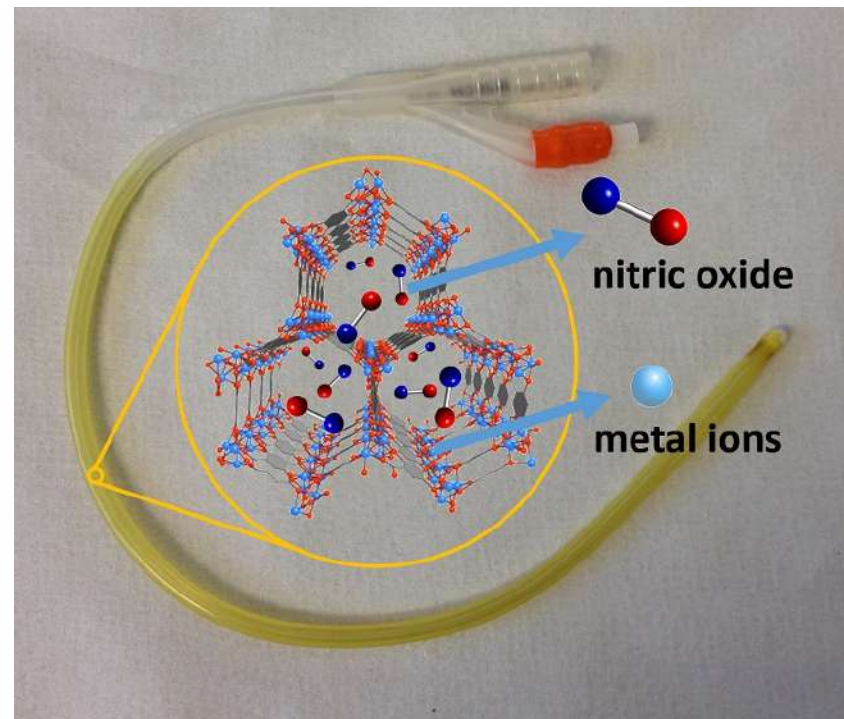


**III International Scientific Conference “Preservation of Cultural
Heritage” BASA' 2019
21-23 November 2019, Sofia, Bulgaria**

SOME NEW EXPERIENCES IN BUILT HERITAGE RESTORATION

Dr Nadja Kurtović-Folić, Dr Radomir Folić

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The text includes the following sections:

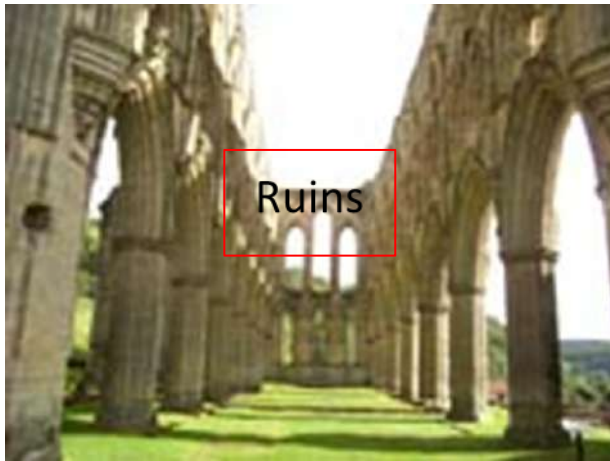
- **Introduction** - some of the most influential views on restoration
- **Some new experiences in built heritage restoration**
- **Concluding remarks**

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- **In all areas of work, including certainly work on cultural monuments, the question arises from which of their past we begin to consider the problem.**
- **Is it a total past, or is it a past of cultural monuments that we find today when we begin to deal with it?**
- **The reason for this question is the evolution of restoration concepts that has left a mark on the legacy that we find today in a particular physical state.**
- **Here we can recall some of the most influential views.**



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- **E. Viollet-le-Duc (1814-1879): “The structures and researching old texts and construction documents are of great importance”.**
- **C. Boito (1836-1914): “The modern materials and modern techniques should be used to a minimum”.**
- **G. Govanoni (1873-1947): “Modern techniques, especially the use of reinforced concrete, should be used where traditional methods and materials are not sufficiently reliable”.**
- **A. Evans (1851-1941): used concrete in large quantities and thus significantly influenced the increased use of this material by other conservators.**
- **N. Balanos (1860-1942): accepted reinforced concrete, considering it a useful, solid and durable tool for the restoration of most important Greek ancient monuments.**

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- **These views were merely a preparation for final acceptance and recommendation for the use of all available modern techniques and materials, especially reinforced concrete, as concluded in the Athens Charter in 1931.**

**ATHENS CHARTER
FOR THE
RESTORATION OF HISTORIC
MONUMENTS**

**International Committee on
Intellectual Cooperation
1932**

5. Modern techniques and materials may be used in restoration work.

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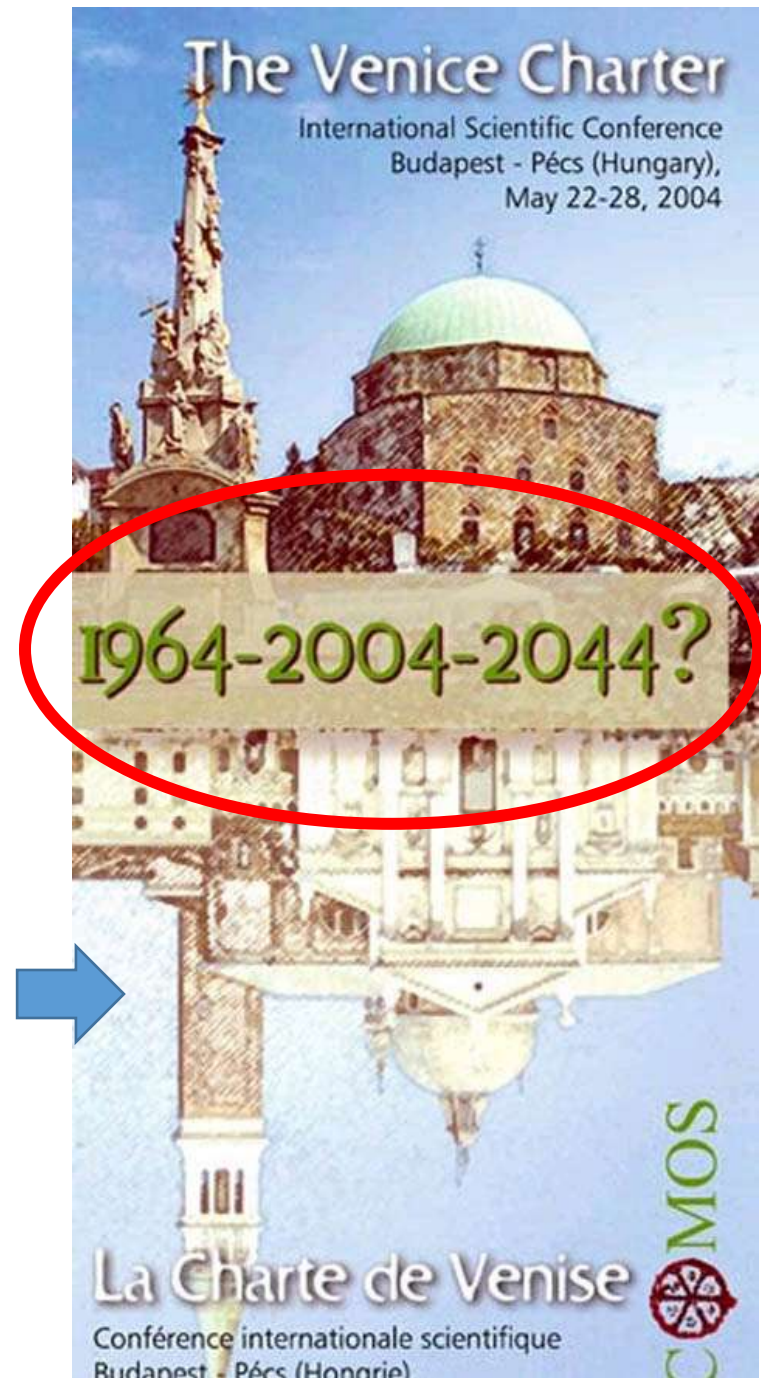
- The most important document adopted after the World War II, the 1964 Venice Charter, recommends the use of traditional materials for structural stabilization and general restoration.
- New materials and techniques should be used only in cases where traditional materials cannot

The Venice Charter 1964

The Venice Charter for the Conservation and Restoration of Monuments and Sites

1. Concept of historic buildings extended to include groups of buildings.
2. Conservation of buildings should not change ornamentation or layout.
3. Restoration—only where necessary, but no reconstruction. New elements should be distinguishable.
4. Elements of value from any period should be respected.
5. Falsification in replacing parts should be ruled out.
6. rehab of archaeological sites should not alter buildings to enhance understanding.

← CHANGE OVER TIME →



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- **Today it does not raise the question of uses new materials and technologies.**
- **They have become indispensable, because their composition and method of application is such that it can fulfill the basic principles of protection of the built heritage.**
- **Architectural heritage shapes from a relationship between “built” and “void”, masses and details, as synthesis of materials, constructive systems, aesthetic characteristics, and spaces able to accommodate human activities.**
- **This “able to accommodate human activities” drives conservators to change their stance on new materials and technologies**

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Some new experiences in built heritage restoration

- **Certain conservators still believe that it is best to use original materials, which means traditional wood, stone and brick (as well as iron and glass in original processing).**
- **However, when analyzing the processes of work on such treated buildings, it is almost certain that at least one part of the jobs in which new materials and techniques have been applied will always be found.**
- **In addition to new materials, traditional materials that are technologically innovated and preventively protected are nowadays also included in the work process and should be accepted as a specific form of new experience in conservation and restoration of the built heritage.**

New materials and technologies are being applied in several of the most significant processes of conservation and restoration work such as:

- structural stabilization of the historic building or its remains;**
- architectural conservation, restoration and reconstruction;**
- during major interventions on the whole cultural monument or on extensions they are most often needed due to a new functions or the incorporation of smaller historic units within latest complexes of buildings.**

- **It can not be pointed here all new materials and procedures that today produce good results.**
- **But, all of them have to meet three basic technical protection criteria:**
 - **minimal intervention**: means that the expressive qualities of the building and environment resulting from its original form and all other significant changes that have followed over time must not be destroyed by new works on heritage.
 - **compatibility**: means that the characteristics of the materials used in the conservation and restoration work, especially new materials, must be harmonized with existing materials.
 - **reversibility**: means that all applied works can be removed and replaced with new, appropriate measures if new knowledge about the advancement or innovation of conservation materials and techniques is obtained.

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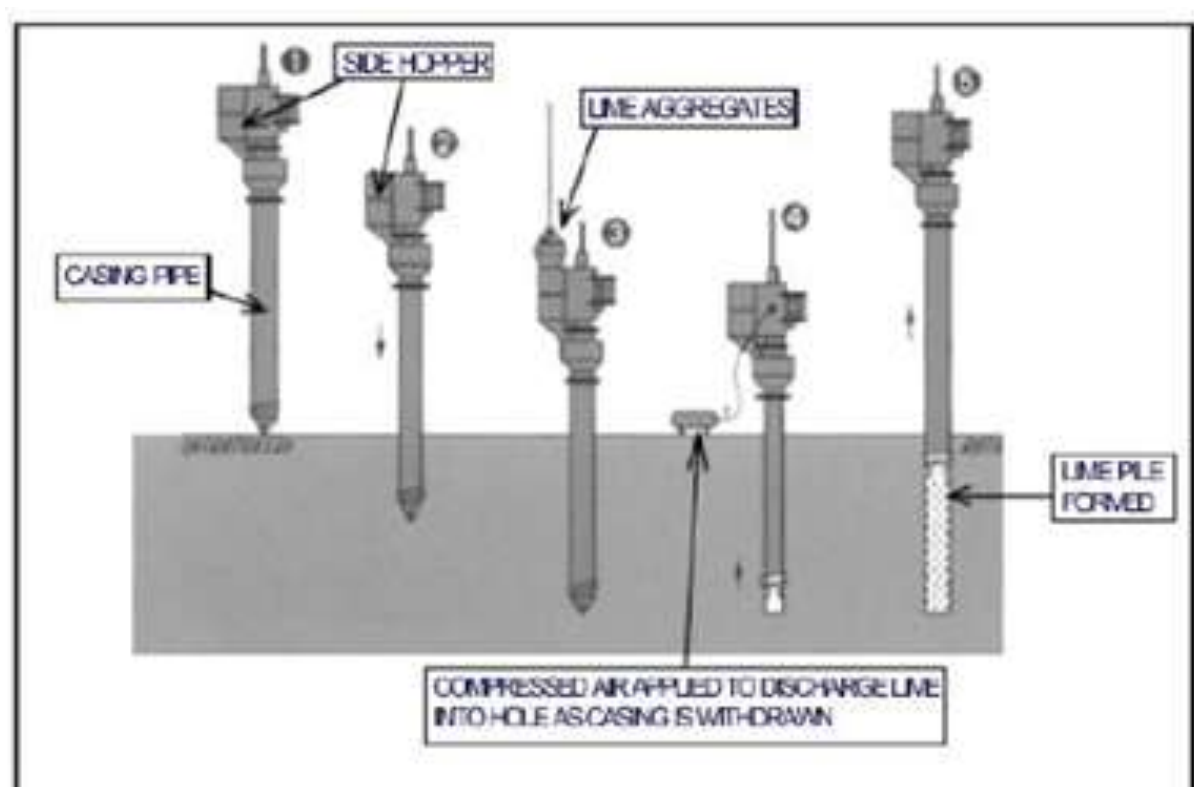
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Some inovations in soil reinforcing techniques

- **Reinforcing the soil above which the historic buildings were erected is a very delicate task.**
- **Some soils are expansive because they contain minerals such as brown clay, which absorbs water and varies in volume (shrinks and expands). As a result, forces occur that cause cracks in foundations, floors, and walls in lower zones.**
- **This is a problem for which innovative techniques and materials have been devised in recent years that depend on the use of natural materials that strengthen the soil, do not pollute the environment and significantly strengthen the historic character of the building.**
- **At the same time, these are approaches that successfully mitigate the risk of an earthquake.**

- Very simple and good method is known as “LIME PILES TECHNIQUE” [2]



After lime column installed, the lime or calcium is pumped into soil surround the lime pile and that will change the soil properties around lime column resulted by the chemical reaction between lime and soil.

This mechanism will control the strength of the soil surround the lime column.

The most dramatic improvement occurs in clay soils of moderate to high plasticity.

- Benefits:
1. Plasticity reduction;
 2. Reduction in moisture-(drying);
 3. Swell reduction;
 4. Improved stability.

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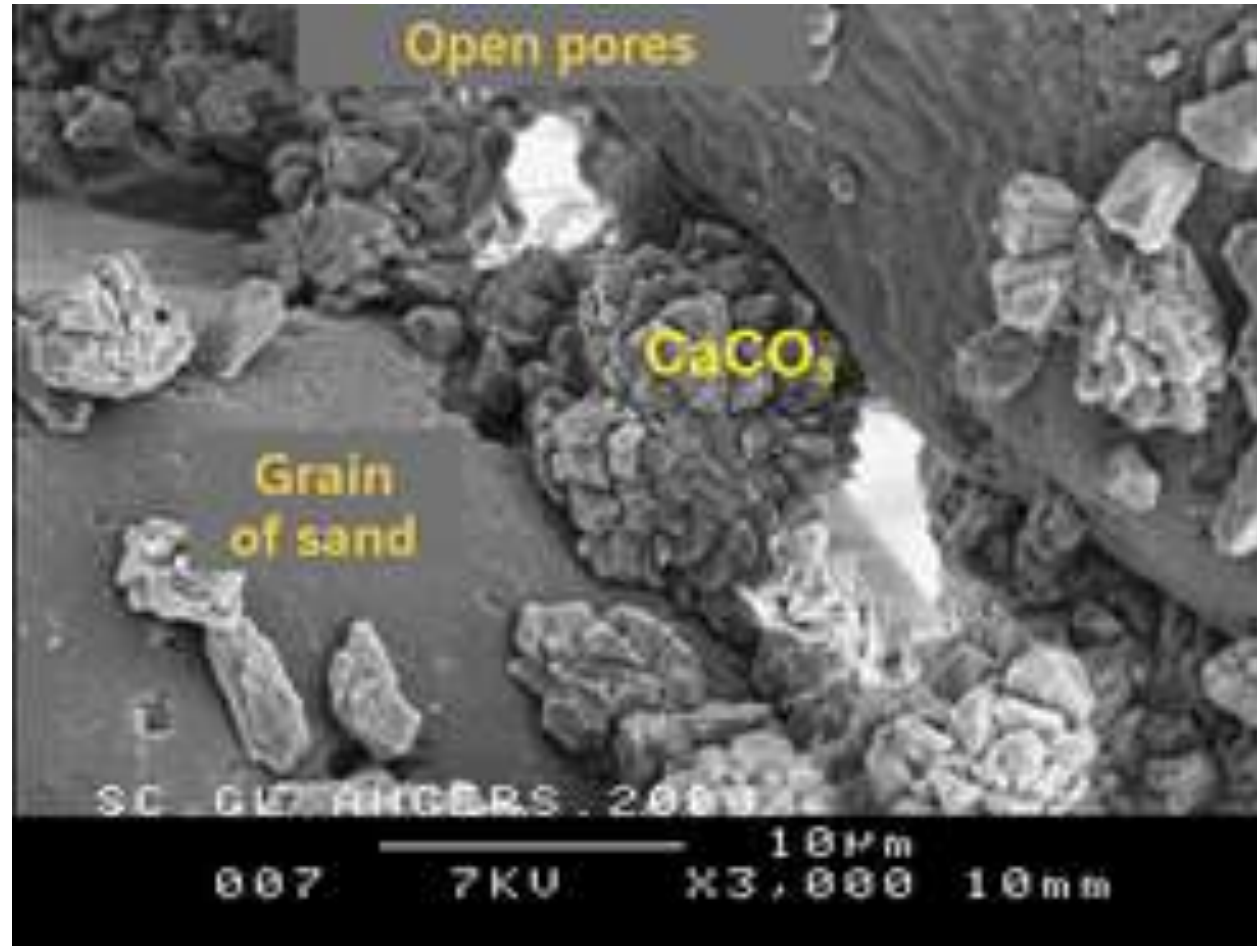
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- **Ground improvement through a natural process was developed by the company Soletanche Bachy.**
- **This is a method which use biocalcification, called Biocalcis®.**
- **The process respects the environment and delivers a major increase in the mechanical resistance of soils and in their cohesion, without a significant change in their initial permeability.**
- **Biocalcis® mimics the natural process of calcification.**
- **The procedure is based on enzymatic hydrolysis of urea in the presence of Sporosarcina pasteurii bacteria, followed by precipitation of calcite in contact with a calcifying nutrient solution.**
- **Biocalcis® won the French National Public Works innovation award in 2015**

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Microscopic slide showing soil calcification (after [23])

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Conservation and restoration of built heritage architecture and construction

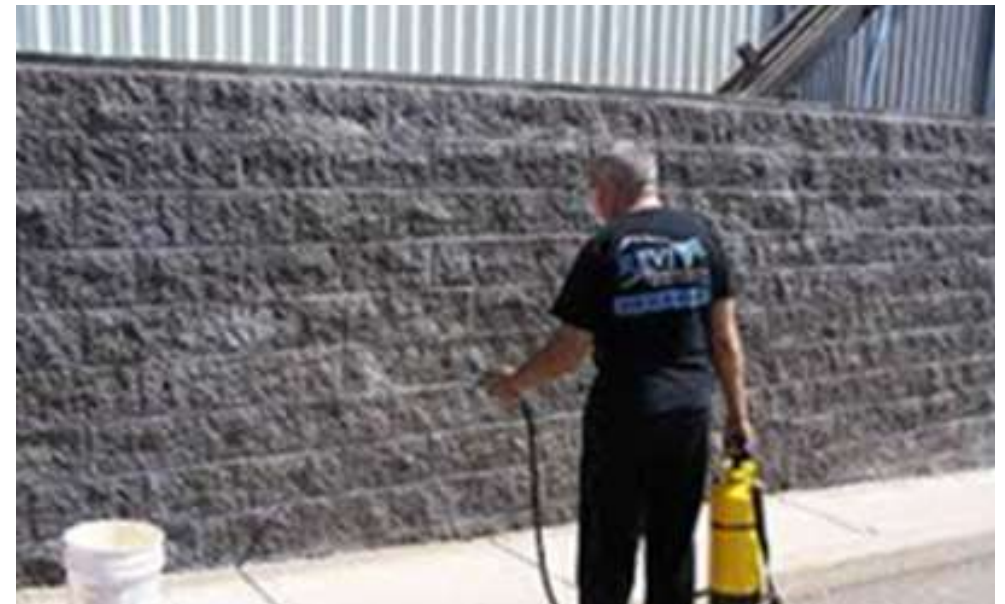
- **In this area of technical approach, one of the biggest problems is protecting the walls from moisture and salting, which is characteristic of traditional materials.**
- **Over the course of time, a number of different coatings have been tried that could slowed down or completely prevented the problem.**
- **Today, the most commonly used cement mortar is almost completely discarded, and in some countries it is banned.**
- **It is constantly experimenting with mortars that should be able to remove portable salts from the mass of the wall while maintaining its durability.**

- **Some of the most significant experiments are related to the influence of natural zeolite as an additive in lime mortars.**
- **Basic physical and mechanical properties such as absorbability, capillary absorption, density, total porosity, compressive and flexural strength were tested in the laboratory and the results were compared.**
- **Specific additives such as: hydrophobizer, methylcellulose-water retaining additive, vinyl acetate and ethylene copolymer powder, the redispersible additive for improvement of adhesion have been used.**
- **Experimental results have shown that mortars modified with natural zeolite stand out due to their good sorption properties and can absorb a sufficient amount of salt.**
- **Lime mortars with natural zeolite are completely complementary to traditional materials and can, without fear of bad consequences, be used in the restoration of built heritage.**

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Condition of the plaster samples after examination on resistance to salt crystallization



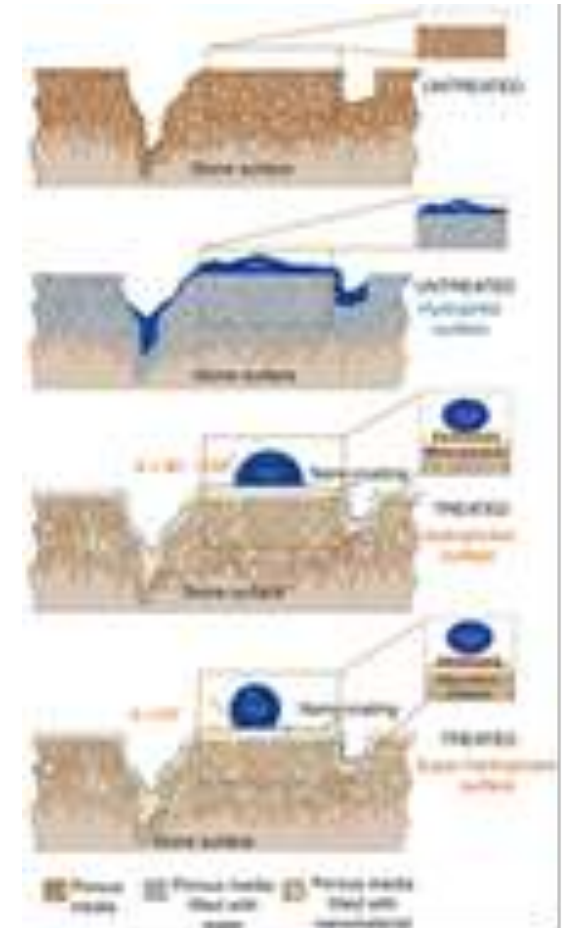
Natural zeolite based coating

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- **In addition to the TiO₂ nanoparticles dispersed in an aqueous colloidal suspension, a range of new nanomaterials are being used, based on the advancement of some of the already known particles and compounds.**
- **New material with properties suitable for eco-sustainable applications in cultural heritage as protective coating are continuously testing.**
- **Interrelationships among structure, properties and uses in conservation of this kind of nanomaterial are highly appraise.**



Static contact angle of a water drop of untreated (a) and (b) treated limestone by a water repellent product based on nanomaterials (after [22])

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The recipes of many mortars/ plasters from certain historical epochs are known today and can be purchased as ready-made mixtures, which greatly speeds up the repair the wall surfaces and repointing operations.

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- **In addition to new solid wall coatings, recipes have been refined to protect the original elements.**
- **One of the highest quality recipes, the composition of which is not fully known, has been used for years as the protective coating of elements of the wooden roof structure of the Church on a hill in Sigişoara, Romania.**
- **The Romanesque Church, originally dating from the 13th century was restored in the Gothic style.**
- **This refined piece of religious architecture has an exceptional high-rise roof construction, which is mostly original and protected solely by coatings every two or three years.**

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Church on a hill in Sigișoara, Romania

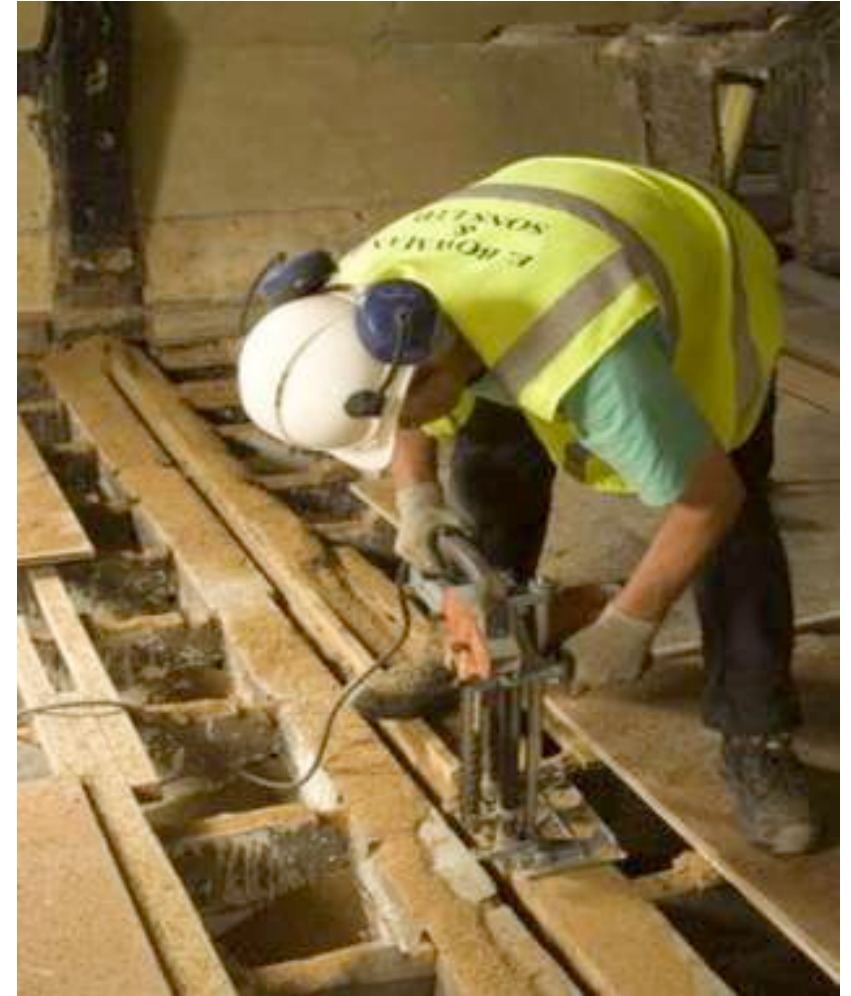
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- **When it comes to stabilizing whole structures or debris of built heritage, the use of reinforced concrete is almost completely replaced by various metals and fiber-reinforced plastic (FRP).**
- **Steel reinforcement elements are used as visible or hidden depending on the principles that the conservator accept.**
- **Two examples are presented here to address this difference in approach**

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Visible and hidden use of steel elements for reinforcement of the floor beams

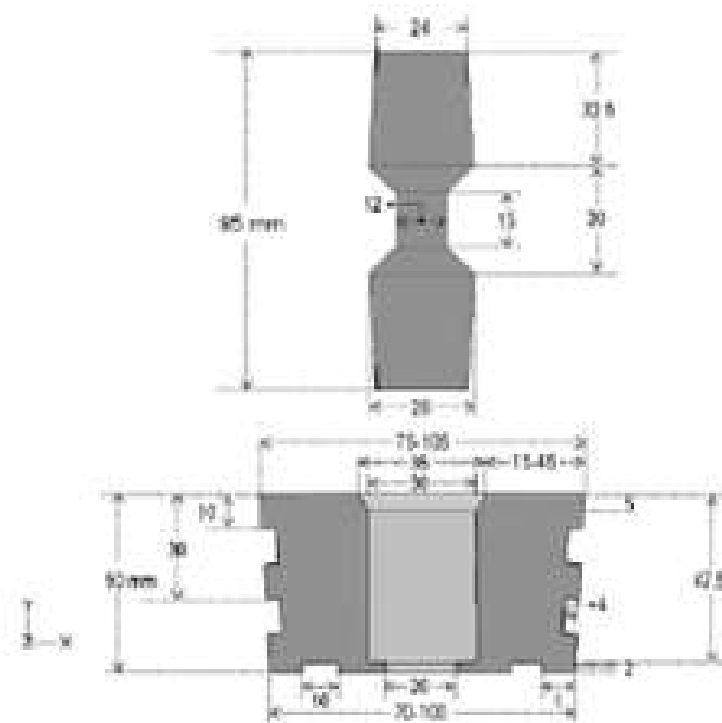
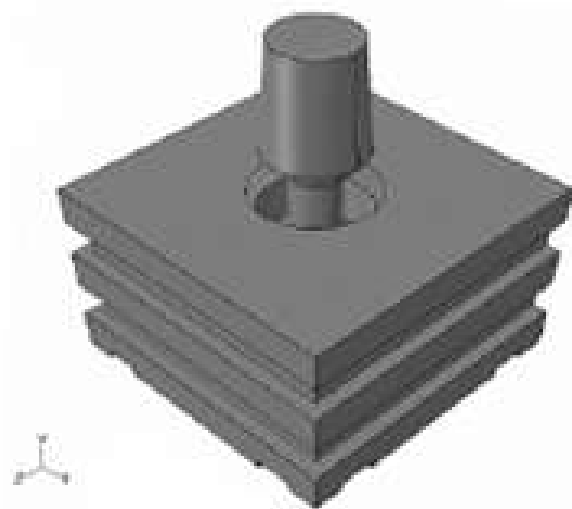
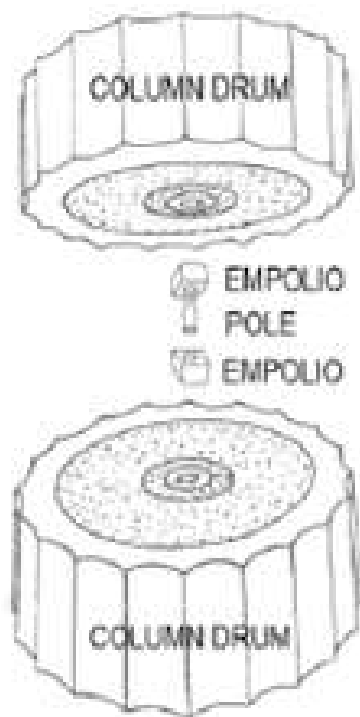
- **The aforementioned titanium, laboratory-processed in coating, is used in its original form, as a metal that is embedded to stabilize historic buildings.**
- **It is widely used in the protection of ancient Greek buildings, of which the writings Vayas and Papadpoulos are very exhaustive:**

“One of the most characteristic aspects of the modern restorations of ancient monuments in Greece is the extensive use of titanium for: i) the reinforcements of broken architectural members, and ii) for the new connectors constructed to replace the ancient wooden poles and empolia in columns interfaces and the iron clamps and dowels of the stone blocks. Titanium was chosen for these applications due to its high resistance to all types of corrosion and its high strength in combination to its low weight”

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Drawings presenting the connectors between adjacent drums of classical columns (left) and the new titanium connectors for the columns of the temple of Apollo Epikourios (after [26])

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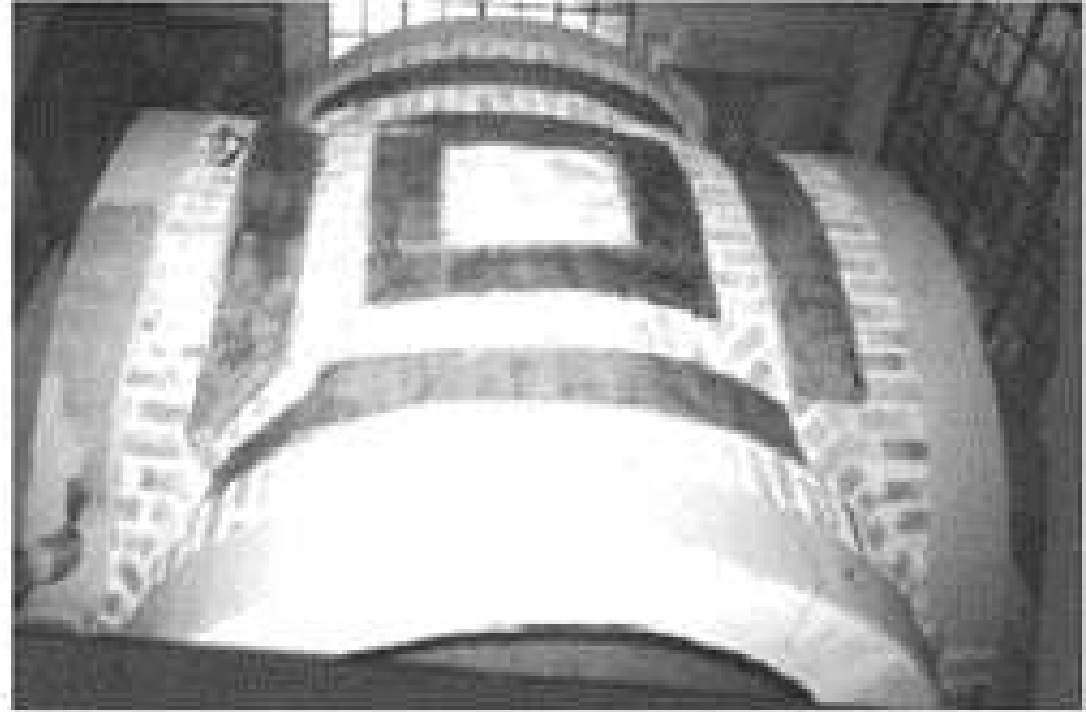
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- **Much has been written about the use of FRP materials and their application has been shown through numerous examples, so here it is only referred as a form of protection that is constantly being improved for a variety of cases.**
- **The composite fibres with high modulus of elasticity and tensile strength can increase the in-plane and out-of-plane strength of the masonry wall, columns, vaults and domes.**
- **Fibre-reinforced plastic is also useful in terms of corrosion protection such as stress corrosion cracking.**
- **Fibre-reinforced plastic is produced using a wide range of fibres depending on the final usage requirements.**
- **Fibers can be sourced from glass, carbon, aramid, basalt and other sources.**
- **It is vital to ensure that the fibre source of fibre-reinforced plastic suits the application that it is to be used in.**

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Different uses of FRP reinforcement (after [1])

Large-scale modern interventions on built heritage

- **In the last few decades, the professional attitude has significantly changed in relation to the restoration of the architectural heritage.**
- **It is now insisting on a clear, but subtle distinction between the old, original and new elements of the building.**
- **That is very difficult to achieve, In order to overcome this problem and to ensure that adding materials and applied technologies would act as integral parts of the restored building in each, even aesthetical way, and the conservators started with the application of new materials and technologies.**

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- **Repair of built heritage take place in the context of a set of requirements, which range from philosophical to purely assumptions and constraints.**
- **All the requirements influence the advanced methodology of the mixed design.**
- **Before starting the discussion on restoration of an historical building with large interventions or extensions many aspects have to be evaluated in conjunction with one another.**
- **Practice has proven that approximating the restoration of built heritage solely from as a technical point of view, will easily lead to the interventions, where basic aspects such as authenticity and the historical context are neglected or insufficiently seriously considered.**

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- **The need to change the function or increase the capacity of a historical building is currently the most challenging reason for specific forms of restoration followed by large extensions of the structure.**
- **Changes in buildings, which allow them to gain a new purpose or use, often represent the only way to ensure survival and a sustainable future.**
- **Getting the right balance between development requirements for conversion, construction regulations and special needs of cultural monuments is a very demanding task that is solved with the help of numerous specialized expert teams, as well as negotiations between different stakeholders in the venture.**

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- **The traditional selection of new functions such as museums, galleries, cultural centres, souvenir shops is also overcome and the number and type of new purpose of old structures is very wide.**
- **Today, it is no longer surprising that churches are converted into comfortable living quarters or industrial halls in shopping malls, town houses in gym.**
- **In this way, preserved and renovated historic buildings enrich the city's cultural image and lifestyle.**
- **Restoration of built heritage is a process that is constantly refreshed with new ideas, techniques, technologies, and follow the civilization development of the society in which the events unfold**

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- **Nowadays, there are still three options of restoration method, and there is an international debate which of them is the best one for the historic building:**
 - **The first option is that the aspects of materiality and aesthetics appear as integral parts of restored building.**

**Heritage restoration by
using concrete elements**



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- In *the second case*, restoration is achieved by the use of extremely contrasting materials that complete the missing parts of the historic building.
- Golden gate of the Diocletian palace in Split, Croatia



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- **Third approach uses new materials and technologies that enables the simultaneous perception of the historic building in both its original whole and ruinous state.**
- **The emerging technologies have set ground for using several already known materials, but improved in structural way minimizing the need for substructure and maximizing transparency, while protecting the existing sensitive historic materials.**
- **Contemporary conservation approach aims to actions that should be distinguishable in order to reflect their time and avoid falsified interpretations of the original structures.**
- **On the one hand, the stratification of the historic building should not by no means be concealed and on the other hand the new materials should not be disguised, enabling an honest dialogue between old and new, the past and present.**

- **One of the crucial principles, the principle of reversibility suggests that every intervention should give the possibility for future removal.**
- **The conservators find themselves in an internal conflict, being asked to respect and leave the monuments in the state as it is applying reversible method, but at the same time efficiently safeguard for future generations.**
- **The objective is clear: to emphasize the imposing historical building by adding a new layer to the landmark, a fashion statement in the form of a complex building overlooking the city.**
- **More and more designers and conservators together decide that old-new combined structure does not try to blend in or to hide its modern extension appearance.**
- **They threatened this approach as a fitting apotheosis for what was, until recently, a heap of crumbling structure.**

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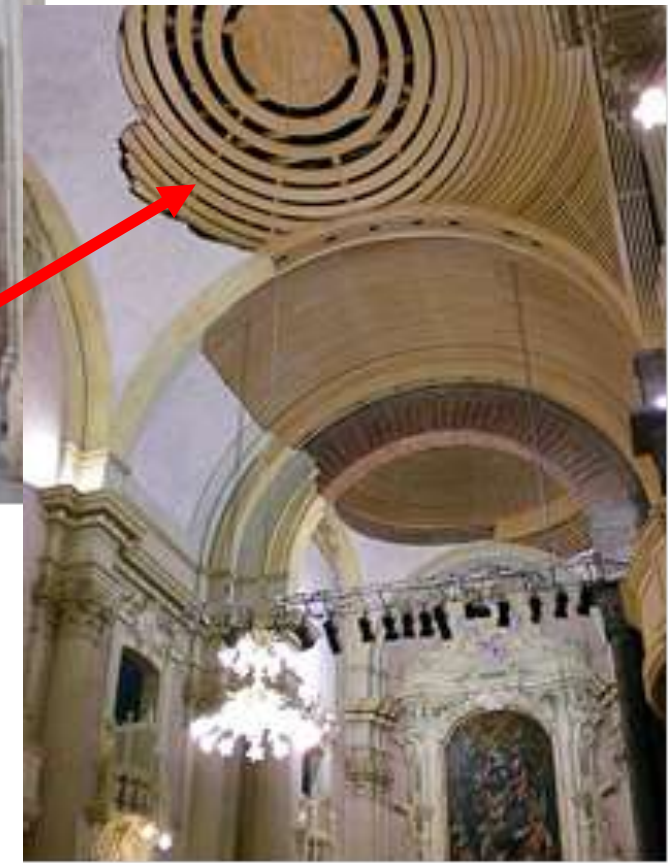
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- **In addition to brand new materials, traditional materials are technologically advanced and are extremely effective in complex process of restoration of historic building with new extensions.**
- **Wood, as an old building material, has significantly changed its properties due to the technological innovations. It is very flexible and prepared so that it has become resistant to climatic, chemical, physical and biological effects and is used in the restoration of historic buildings at places unusual for its use through history**

**The new wooden dome of San Filippo Neri,
Bologna, Cervelatti, 2018.**



Wooden barrel vault of the church of S. Maria of Gesù, Modica, Fidone and Messina, 1996Dr



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- **Various iron elements were also embedded into buildings throughout history, but now iron and other metals are processed so that they are perfectly complemented with their structure and surface treatment with the remains of historic buildings.**



Steel profiles and oxidized copper plates to recall the geometries of the cross vaults of the side chapels of the church in the Convent of S. Maria del Gesù in Modica, Sicily

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- **The Basilica of Santa Maria Maggiore di Siponto in Manfredonia has become one of the great attractions that have been visited by hundreds of experts and tourists since 2016. The artist Tresoldi did very bravely majestic architectural sculpture of steel wire mesh that tells the volume of the existing early Christian church and update the relationship between the ancient and the contemporary.**



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- **Stone** as an old building material is now used in different, creative way.
- The facades of new tracts consist of open-spaced horizontal lime stone strips that harmonize with the old stone facades and also allow light to enter the linking corridors.



**Extension of the old warehouse
in Würzburg
with lime stone strips**



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- **In architectural restoration the transparent elements should contribute somehow to the consolidation of the damage historic building and encourages the use of materials with inherent transparent and structural properties.**
- **Glass is the only one that creates an almost dematerialized intervention due to its transparent properties, durability and highly compressive strength [3]**
- **Restoring a damaged building by glass is the closest action of not restoring it at all. 'All traces of history are free to narrate their own story as 'wounds that are healed but not hidden' [8].**
- **Trough transparency of the glass, the historic buildings are related in a direct and honest way to their surrounding the present setting.**

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- **The use of glass in the restoration of historic buildings can be twofold. The first approach could be called the conventional use of glass as a protective structure, the most common archaeological finds.**

Bayazit Library, Istanbul



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- **The second approach is very creative, imaginative and it brings to light all the qualities of glass as a restoration material.**
- **One of the finest example of creative use of glass could be seen in Pozzuoli, Italy. The ruins of the Augustus Temple are restored with a glass façade that consists of fins and plates outlining the shape of the original columns. Some details are really very original such as detail of the current entrance with pronaos columns serigraphied on the plate glass.**



- The flexibility in forms that can be attained using cast glass is the best solution for restoration treatment aiming to resemble the original shape as faithfully as possible.
- As a case study, the restoration of the Lichtenberg Tower in Maastricht is proposed. The Lichtenberg Tower - the oldest castle ruin in the Netherlands – could be restored with glass components that fill the missing parts and prevent the monuments' walls from drifting apart and collapsing.
- The innovative contribution of this glass restoration approach, besides allowing for a transparent addition, lies in the development of a completely reversible system [19].



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- The use of extruded glass could be adequate for the restoration of linear structural elements, such as the gothic columns in the standard cross-sectional area.
- A modern and abstract configuration of extruded glass is also possible to be used in the form of truss structures, to create lightweight horizontal components.



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- However, *the combination of steel elements and glass surfaces* is most popular solution and often used during restoration of historic buildings in the last decades.

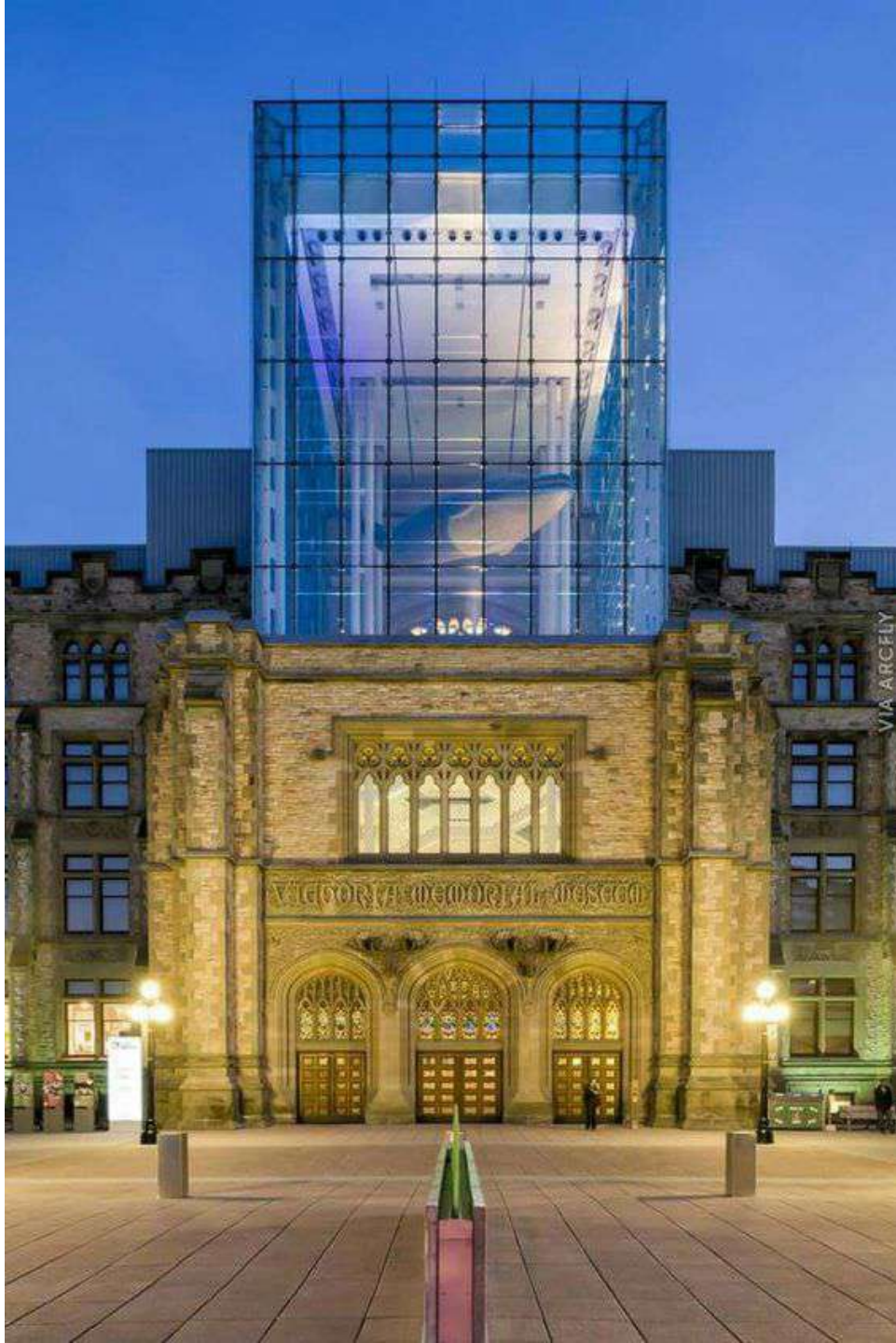


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- **The use of new materials and technologies in heritage restoration has undoubtedly significantly altered the conservation principles used by conservators in the 21st century.**
- **New combinations of old, traditional, technologically innovated materials are constantly emerging.**
- **The fact is that such bold actions, like historic buildings getting large extensions, are undertaken by exceptionally talented architects, who are not conservators by definition.**
- **They dare to put their creativity on trial and exposed to the court of the public.**
- **Undoubtedly, they followed the basic conditions and principles of conservation, but, like their predecessors from history, they treated construction as a process that is constantly refreshed with new ideas, techniques, technologies, and following the civilization development of the society in which the events unfold.**
- **Many ways to encourage further research on this topic are just opening up.**



THANK YOU FOR KIND ATTENTION!