Article

A conceptual design approach for archeological structures, a challenging issue between innovation and conservation: a studied case in the ancient Pompeii

Abstract: The preservation of the authenticity of a building artefact is a responsible practice. On the other side, the need to save the building artefact from the natural and anthropic degradation, to ensure the structural reliability to the different actions, to define an efficient maintenance program are big challenges, that involves the cooperation of several professionals, responsible use of innovative techniques and materials that are nowadays available. This paper focuses on a specific design approach for the rehabilitation works of ancient constructions in archaeological sites. The proposed conceptual design approach implies different steps that allow the optimization of the design at an increasing level of knowledge on the existing structures and their materials. The design procedure on historical constructions generally includes the following steps: the collection of data, the structural identification, hazard, and vulnerability analysis, damage and risk analysis, a cost-benefit analysis, so only at the end of the process, the final design is achieved. In the archaeological area, some important design aspects cannot be defined before the execution work phase, since some elements could be revealed and identified during work execution, as a consequence, the final design has been often optimized after all this information has been acquired. A studied case in the archaeological site of Pompeii is herein presented to prove the efficiency of the proposed approach.

Keywords: cultural heritage, masonry rehabilitation, seismic device, steel structure, basalt fiber, grout injections, archeological site, rubber-bearing, non-destructive testing.

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Buildings* **2021**, *11*, x. https://doi.org/10.3390/xxxxx

1. Introduction

The design process in archaeological sites is normally complex, as soon as several constraints influence the final results. Often, the need to protect decorative surface in archaeological sites yields to build new roofs, as a consequence an extensive strengthening on the masonry walls should be made. Alternatively, the protection of the surface could be obtained with provisional roof structures or with roofs standing alone having a proper structure and foundation, this solution could be very invasive in the archaeological space [1, 2, 3]. In the design process the decision making phase, in order to define the types of intervention, materials and technologies is crucial for an optimum rehabilitation project. The design choice decision is animated by intensive discussions among scientists, architects, engineers and archaeologists that face the problem and propose design solutions from their particular prospective. The optimum design should be found considering and weighting all different aspects, by using a cost – benefit analysis that is oriented to the preservation of the material fabric with a reduce invasiveness of the intervention works.

All rehabilitation measures aim to a conservation oriented objective that excludes as far as possible the demolition or replacement of material or structural elements [3]. In a historic building, actual consolidation practice and experience, based on the contemporary knowledge, has introduced a broad spectrum of materials and devices able to improve its

 doi:10.20944/preprints202102.0382.v1

performance when subjected to static and dynamic loads [4, 5]. In this context the use of steel is very prominent as far as its high characteristics of reversibility made steel very useful in the cultural heritage environment. On the other side, most designers are often oriented to use compatible and natural materials, such as wood, stone etc. [5, 6, 7, 8]. For these reasons, during the design process, the decision on the type of intervention and material yields to a different level of safety.

The present paper presents a design rehabilitation approach aiming to consider the constraints coming from the material fabric, the conservation principle, and the structural performance and safety. The design process on heritage masonry structures are a very challenging task, the need of reversibility and no-invasiveness of the interventions require a great attention, especially if the artefacts are archaeological structures. The constraints coming from the conservation theory made rather impossible to reach the performance level as defined by the seismic codes in new constructions for the required probability within a specific conventional life [4]. Strengthening design on archaeological structures in order to meet the requirements of seismic codes often leads to invasive interventions that are not compatible with principles of conservation.

In literature most authors focused their attention on testing and monitoring of the structural properties of buildings and monuments [5, 6, 7, 8, 9, 10, 11, 12] in order to understand the rehabilitation needs of the structures. Few authors, interested to assess the structural challenges in archaeological sites, have investigated on the aspects related to the challenge to consider both seismic requirement and conservation of material fabric [13, 14, 15].

The proposed interactive design approach, based on an extensive experimental testing results allows the professionals to optimize the design, and to choose where to localize the intervention, to introduce innovative design solutions and new materials, respecting the principles of restoration for Cultural Heritage and the constraints of Seismic Construction Codes [4].

The design approach is herein applied in the archeological area of Pompeii, in particular the studied case presents new design solutions, introducing new materials for rehabilitation and rubber devices in this peculiar environment.

The present paper aims to highlight some important aspects of a rehabilitation design process. First, the rehabilitation design of ancient structures needs always an extensive experimental campaign aiming to know the geological and geotechnical characteristics of the soil foundation, the material features, the structural conservation level of all elements, the types of connection between walls, the construction details, the nature and location of the foundations [6, 7, 8, 9, 10]. The simple visual inspection is often not sufficient to complete knowledge of these structures, the use of non-destructive testing [11, 12, 13, 14, 15] is a valuable tool to understand the structure and to build a reliable model that allow to simulate the structural behavior [16, 17,18]. In archeological site, some testing could be performed only during the work execution, for examples some preliminary works or excavations could be needed to complete the design process. As a consequence, during execution works the efficiency of the proposed rehabilitation solutions [16] can be usefully evaluated through experimental testing, by using ground penetrating radar, sonic tests [13] and topographies, combined with material testing on mortar and natural stones of the masonry walls. The assessment of the effectiveness of the strengthening technique yields consequently to the improvement of the design process and a refined localization of the consolidation intervention.

Secondly, the paper introduces the use of new materials and devices for upgrading the structural performance under static and dynamic loading. Nowadays, new technologies for repairing the structures, compatible with the historic fabric are available on the market.

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Specifically, the paper presents an application of a new material such as basalt fibers, used together with natural grout injections in the mortar joints. This technique, compatible with the original material fabric, has proved to highly increase the quality and resistance of the masonry walls in archaeological sites.

Moreover, the paper presents the application of seismic devices, that is a very promising technology to protect the masonry structures to contrast damages due to horizontal loading. Historical buildings are usually characterized by relatively low height and high stiffness, that corresponds to a low period of vibration. For such buildings, located in seismically active zones, seismic isolation systems could be very effective solution for improving earthquake resistance of these structures. The main advantage of a seismic isolation system is that no structural elements should be added to the structure in order to strengthen it [18, 19, 20, 21], while the traditional techniques, oriented to increase strength and ductility, are not always useful in the seismic rehabilitation of complex masonry structures. The aim to reduce seismic actions, thus avoiding significant damages to the structure and its contents even under strong earthquakes yields to successful results, since the devices could interfere moderately with the structure itself [18]. The severe damage in masonry buildings due to earthquakes has evidenced the need of studying new seismic protection techniques in order to guarantee appropriate safety levels against earthquakes and also a minimum impact on the material fabric. The Base Isolation System (BIS) balances the opposite requirements of structural safety and architectural preservation [19, 20, 21,22, 23]. In literature, there are few examples of application of base-isolation to protect artefact, in particular the use in archaeological sites is even more rare.

The present paper presents an application of rubber bearing, that are installed between the masonry walls and a new steel roof. In this case the rubber bearing devices are used to disconnect the roof from the masonry walls in order to protect the underneath ancient walls from the horizontal forces.

The application of the design approach discussed in paragraph 2 and some details regarding the rehabilitation works will be shown in the following. The rehabilitation works and the new roof in the Championnet area of Pompeii (*Regio* VIII, 2, 1-2-3) will be presented in paragraph 3.

2. Conceptual design approach

2.1. Design decision making analysis

The structural design on cultural heritage artefacts depends on several aspects mainly related to the existing damage level, the constraints due to the need of preservation of the historical fabric authenticity, the presence of decorative surfaces to be protected, the expected benefits and improvement in the structural behavior coming from the rehabilitation, the planned structural use, the time period between two consecutive maintenance interventions. The decision making process is really articulated, that can be summarized shown in the flowchart in Figure 1, it needs several information regarding the material fabric, that can be obtained with experimental testing, documentation of previous restoration works, other information regarding hazard, vulnerability and risk analysis. A reliable structural model of the structure is needed. The design involves a decision making process to define the level of intervention, and at each of them it corresponds a different level of safety. Herein four levels of intervention have been identified: maintenance, rehabilitation, retrofit, reconstruction (in general partial reconstruction on cultural heritage structures).

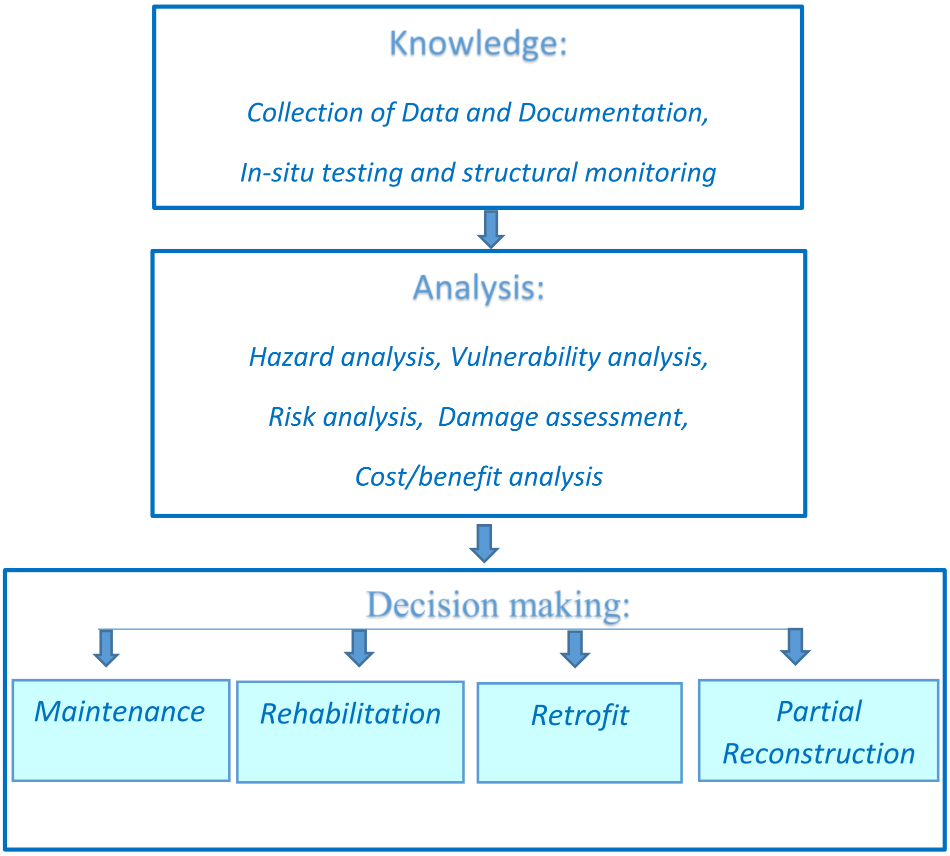


Figure 1. Design process on cultural heritage building.

Generally, a preliminary design developed on the basis of the knowledge on materials, and on structural details coming from the literature and available documentation, allows a definition of preliminary numerical analysis, consequently to evaluate the level of invasiveness of the first hypothesis of interventions, in the meantime to assess the corresponding target level of safety and benefit. Consequently, a first decision can be made on the four level of intervention herein identified (Maintenance, Rehabilitation, Retrofit or Partial Reconstruction).

In archaeological area, the design process is often more complex, the structural design in archaeological settlement have to take into account all uncertainties in the knowledge of the materials and structural detailing. For these reasons a methodological approach, specific for these peculiar structures, where the preservation of the historical fabric is a predominant task, is herein proposed. The flow-chart in Figure 2 synthetizes the structural design phases, and evidences that some design activities should be defined only after an extensive non-destructive testing campaign. The final design is reached on the basis of the results of diagnostic campaigns that identifies the effective damage state and the resistance capacity of walls and foundations, the knowledge of the material characteristics, the effectiveness of the masonry strengthening, assessed during execution works. Only with these data, the structural model can be finally upgraded and detailing design can be reached.

In the flowchart in Figure 2, the design approach is developed. A first campaign a literature review and documentation studies allow to define a preliminary executive design. Then, after rehabilitation works, but still under construction a second experimental campaign allows to evidence the weak points of the structure and to design localized repairs in order to upgrade the masonry quality where the tests evidence the need. This is an interactive process until the final design is reached, consequently the final structural details are defined as soon as a target quality of the masonry is reached. The final structural model lets then to perform sensitivity analysis and check the efficiency of the repairs and of the proposed solutions.

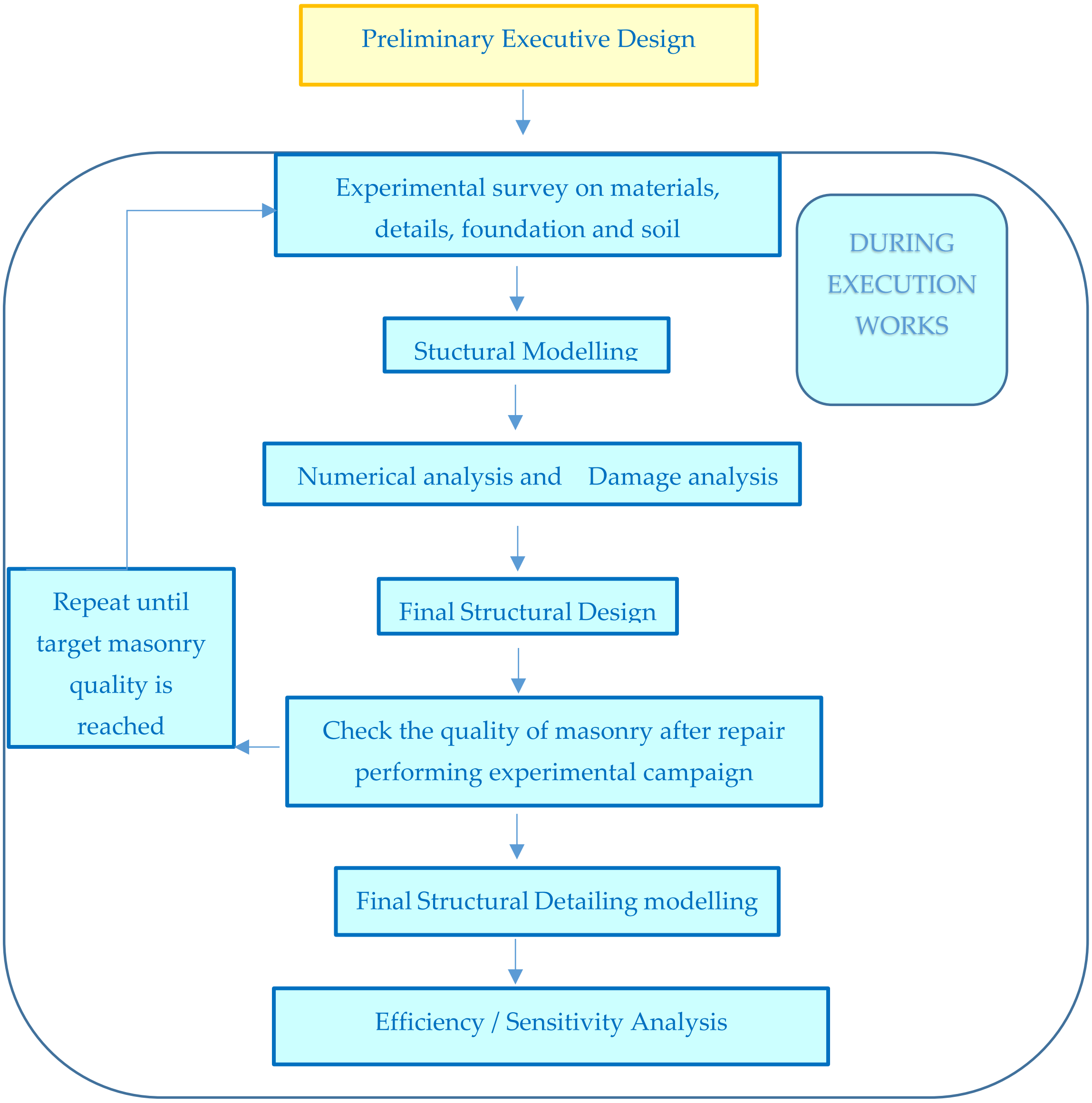


Figure 2. Design procedure in archaeological sites.

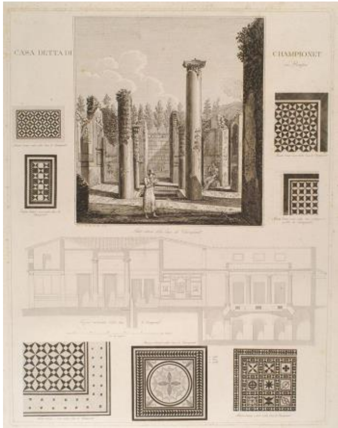
3. A studied case: the house aggregates of Championnet

The proposed design approach has been applied in the aggregate of houses of Championnet, in the ancient city of Pompeii, that has been recently restored. In order to preserve the ancient decorative surface, a new roof having a steel structure and corian slab has been built over the ancient masonry walls. The damage level and the limited thickness of the walls have requested a great attention in design. Following the proposed design approach the final design has been reached after an extensive testing campaign, before and during the restoration work phase, following the design approach in Figure 2.

The rehabilitation and restoration works have interested a wide area located in the Insula 3 of Regio VIII, between the Venere's Sanctuary and the Roman thermal baths of Sarno. This part of the ancient city of Pompeii has three buildings for administrative and public use, and a series of ancient houses located on a cliff with a panoramic view on the sea.

This part of the roman city has a long and complex history, that started on the 2nd century B.C. but successively have been subjected to several transformations until the 79 A.D., when the structures where covered by the volcanic materials erupted by Vesuvius. Primarily, as proposed in parag. 2 a documentation on the aggregate of houses has been collected, Figure 3 a shows some documents, in particular a picture of the area made by Felix Duban on 1987. Figure 4a presents the area before the restoration and rehabilitation works, finished on 2017 during the execution of the *Grande Progetto Pompei*, while Figure 4 b shows the new roofs in steel and corian.

(**a**)



(**b**)

Figure 3. a) The Documentation: the domus of Championnet by Jacque Felix Duban 1987; b) The historic documents regarding Championnet houses discovery, famous for its decorative floors.

(**a**)

(**b**)

Figure 4. The aggregate houses of Championnet: (**a**) before restoration; (**b**) after restoration.

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Figure 5. Foundation sample in Regio VIII.

3.1 The subsoil stratigraphy and foundation analysis

The documentation phase has included the knowledge of the sub soil and foundation of the buildings. The soil under the Championnet houses in Regio VIII has been investigated. According to the data of the performed surveys and the stratigraphy reported by the archaeological excavation essays, the archaeological area is characterized from the lithological sequence detailed in the following Table 1.

The structural skeleton of the new roofs funded on the ancient masonry walls has been made of light materials in order to do not overload the thin foundations and the bearing soil of these ancient structures. The additional loads due to the new roof is transferred indirectly, using an additional masonry built on the top of the ancient walls of the houses. In order to understand the effective load capacity to transfer to the ground, during construction works, some excavation essays have been made to identify the deep and nature, dimension and depth of the “foundation”. In reality, the ancient foundations are underground walls that are thicker 0,30-0,40 m more than the ones in upper part and with more intact and less degraded structure. The excavations revealed that the foundation is not deep more than one meter from the soil surface. Figure 5 shows a foundation sample. The dimensions and depth of these foundations made the structures vulnerable to static and seismic load.

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Table 1. Soil stratigraphy.

Layer	Thickness [m]	Description
1	1	Modern agricultural land
2	1	Repeated layers of ashes, lapilli, lytic levels
3	2.5	*Surge* deposit consisting of ashes, lapilli, lithic levels, organized as a stratified deposit, related to the final phase of the eruption of 79 A.D.
4	0.20	Ashes and pumice fragments
5	3	Pumice unit organized into two subunits due to the central phase of the eruption of 79 A.D., the superior unit made of the typical gray pumice, lapilli and numerous "ballistic clasts"; the lower one composed with a typical white color, lapilli, pumice and "ballistic clasts".
6	0.30	Base ash units relevant to the initial phase of the 79 A.D.
7	4.0	Complex of paleosols, alluvium colluves, soils and anthropic deposits present on site on 79 A.D.
8	5.0	Lava units and their alteration coulters, sometimes separated by epiclastites, attributable to reuption activities prior to 79 A.D.. The lavas occur both with compact and lithoid faces fractured, both with coriaceous faces similar to lava foam and therefore with variable porosity.

3.2 The ancient masonry walls

The archaeological constructions in the ancient Pompeii settlement are characterized by different wall systems in terms of construction technologies, geometries, materials, in particular natural stones and bricks are both used. The walls of Pompeii are made up of regular, but often irregular elements in terms of the shape and lithotypes.

Actually, the chemical-physical and mechanical damage is extensively spread in the masonry walls, affecting the stones elements, the mortars, the top of the walls. This type of deterioration that is concentrated especially in the first one meter in height, even with loss of elements (ashlar and mortar). In general, the rain water and the erosion of the wind have caused most loss of materials. The deterioration processes are related to the absorption, flow and stagnation of rain water. In particular, the tops of the walls are subjected to a degradation due to the erosion and the breakup of large tracts. A first type of damage is determined by the nature of the "mortar" whenever the mortar is made up of a volcanic aggregate with a variable size of 3-4 cm lytic clasts and fine sands, mixed with a low lime component or other binder, this composition made the mortar very vulnerable. The volcanic nature of the aggregate involves the absorption of rainwater and the rapid saturation of the top of the walls. This imbibition process leads over time to consistent loss and erosion of the top of the walls. In particular, the water absorption of the stones/bricks and the mortar of the walls, yields to desegregation with consequent swelling, fracturing and breaking of the masonry.

(**a**) (**b**)

Figure 6. The new roof in the Championnet area: (**a**) a view of the new roof; (**b**) Steel structures before coating

3.3 Innovative aspects of structural design

The innovative aspects of the conceptual structural design of the rehabilitation interventions on the ancient walls and new roof construction (Figure 6) in the Championnet area can be summarized as follows. First, the testing results are herein presented in order to evidence how the test results have influenced the final design, successively, the structural design and its innovation for the archaeological environment are shown. Finally, the efficiency of the proposed solutions is discussed.

3.4 Experimental Campaigns

In order to acquire an appropriate level of knowledge necessary to the final design, four surveying campaigns have been carried out during construction works. These campaigns have allowed the knowledge of the characteristics of the masonry materials, including the structure foundation and its soil.

The characteristics of the masonry walls are investigated through testing on samples of stones picked up from the walls. Seven types of different stones, that characterized the masonry wall in Pompeii, have been subjected to compression tests. Table 2 shows the test results. In particular, the low compression strengths of some stones, called *tufo giall*o and *cruma* are evidenced. These natural stones, very often used in the archaeological construction of the area, affects the whole behaviour of the masonry walls.

The evaluation of the state of conservation of the mortars (Figure 7) and the characteristics of the material have been evaluated through the penetrometer test, which the measures the depth of penetration by inserting a steel needle into the mortar joint. Figure 8 a shows the equipment. The measurement of the penetration of the test needle allows to trace the mechanical properties through some correlation analysis, consequently, the state of conservation of the mortar has been evaluated. The obtained penetration test results are reported in Table 3.

The results of tests made on the stones, bricks and mortar have been interpreted in order to identify the masonry compression strength. The correlation of the data with the ones on similar walls in another ancient house in Pompeii, where a flat-jacket test (single and double jacket) has been performed, have allowed the designer to choice a value of 100 N/cm^2 for the compression strength of the masonry.

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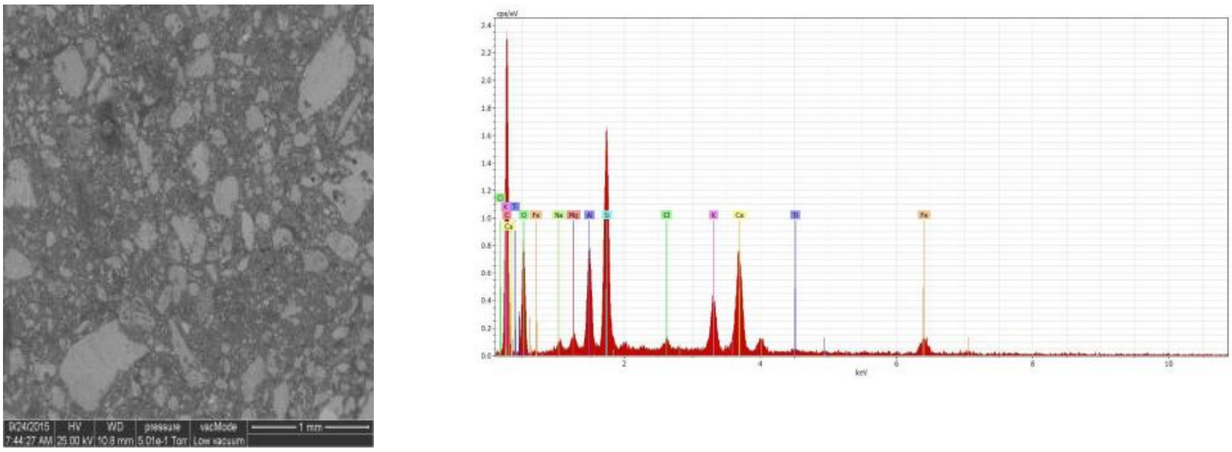


(a) (b)

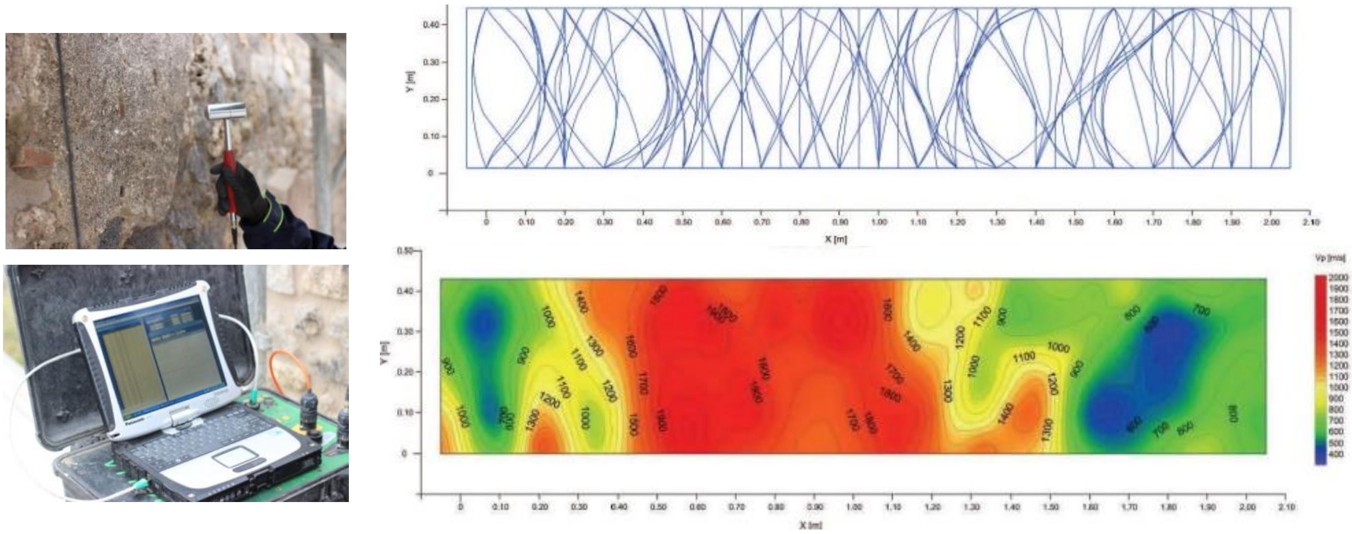
Figure 7. (**a**) Mortar Image at ESEM modality low Vacuum (LV); (**b**) EDS analysis on mortar.

Table 2 – Compression test on masonry stones

Sample	Number Of tests	Volumic Mass [Kg/m3]	Mean square Strength [N/mm2]
Brick	2	1484	5.4
Tufo giallo	3	992	3.4
Calcare di Sarno (Travertino)	3	1279	2.
Tufo grigio	3	1315	12.8
Lava grigia	3	2412	36.2
Schiuma lavica (cruma)	2	867	6.2

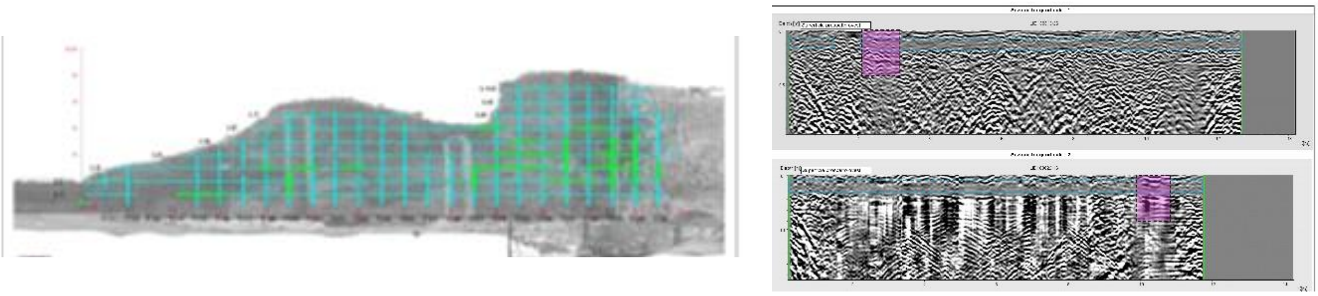
(a) (b)

Figure 8. Tests (**a**) Penetration test on mortar; (**b**) Pull-out test on steel bar.



(**a**) (**b**)

Figure 9. **(a)** Equipment for tomography tests; (**b**) Tomography test results on a plan section of an ancient wall (trajectories of the signals and tomography).



(**a**) (**b**)

Figure 10. Radar test on a structural wall (a), comparison before and after rehabilitation with basal fiber and mortar injection(b).

In order to obtain information about the efficiency of the connection steel roof (between the steel bar bolted to steel plates and the underneath walls), in particular three pull-out tests on the steel bar that connects the steel structure to the masonry walls bar have been conducted, a maximum load of 26 kN has been reached, this proves the efficiency of injection technique with fluid mortar that has been used to lock the bar of the steel roof-skeleton inside the masonry walls. Figure 8b shows the pull-out test setup.

The radar on masonry walls, is shown in Figure 10, this testing has allowed to check the efficiency of injection technique with fluid mortar and basalt fibers inside the mortar joints, that will be discussed in the following paragraph. The comparison of the radar diagrams permits to evidence the area of the wall where the rehabilitation technique has been less effective and where new consolidation has been planned during execution works.

3.5 The Basalt fibre use

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The damage state of masonry is characterized by deteriorated mortars, and presence of holes and alveolization. The ancient walls have been consolidated by injection of fluid mortar and the insertion of basalt fiber nets and ropes [24, 25, 26]. The choice of natural fibers (Figure 11 a) such as basalt in the structural rehabilitation is currently an innovative technique, particularly suited to cultural heritage, as soon as basalt is a natural material with high level of compatibility with the historic fabric. The use of these fibers, as a connection between the existing masonry and the reconstructed portion, is particularly effective for these ancient walls, even if burdened by roofing. The basalt fiber robes have been also put inside the mortar joints in the wall facades in order to increase the resistance of the all system made of stones and mortar.

Table 3. The results of the mortar penetration test and correlated value of compression strength

N. test	Mortar penetration [mm]	Compression strength [N/mm2]
1	25	<0.4
2	19	0.6
3	33	<0.4
4	27	<0.4
5	18	0.7
6	28	<0.4
7	26	<0.4
8	18	0.7
9	25	<0.4
10	26	<0.4
11	21	0.4
12	25	<0.4
13	26	<0.4
14	23	<0.4
15	10	0.6

3.6 The Rubber Bearing Devices

Elastomeric devices in reinforced neoprene have been placed between the roof structure and the walls. The use of such devices is intended to protect the underlying wall by means of a horizontal distribution of shear forces among the walls. This type of application of the elastomeric bearings is new, considering that these devices are normally used to protect the overlying structure.

(a) (b)

Figure 11. (**a**) Basalt fibre ropes in the masonry top wall. (**b**) The rubber support device.

The characteristics of the devices Elastofip 1.5EF 7.2 produced by Fip Industriale (Figure 11 b) are described in the following Table 4. The device is a rectangular block of rubber with the insertion of a number of horizontal steel laminated plates, vulcanized to the rubber, that increase the vertical stiffness and improve the stability under horizontal load. The bearings are designed according to European standard EN 1337-3 in which they are classified as type C bearings. The elastomer which forms the core is made of natural rubber, the reinforcing plates class S355, while the anchoring counter plates are made of class S275.

Table 4. Rubber bearing characteristics.

LIMIT STATE DESIGN	Value
ULTIMATE LIMIT STATE	Maximum compressive vertical load 71 KN Maximum vertical Tensile load 15KN
SERVICEABILITY LIMIT STATE	Maximum compressive vertical load 2-22KN Maximum vertical Tensile load 0 KN Horizontal force 2KN

3.7 The steel roof skeleton

A steel skeleton and Corian® slabs for the roof have been chosen in order to limit the structural overweight (Figure 12). The atrium of the principal house (at number 1, 2 of Championnet Street) is about 9 meter wide, for this reason beams of considerable length have to be put in place, but the corian surfaces on the steel skeleton limit this load on the ancient walls avoiding high compression stress in the masonry.

The problem of transmitting the load deriving from the covering on the underlying masonry has been solved by laying stainless steel plates anchored in the masonry with 2 m long bolted steel bars. During the work execution, some tests have been carried out to extract the anchors to check the adhesion strength and the slip resistance for the most severe load conditions, such as the ascending wind, as previously discussed in paragr 3.4. The results of these tests (Figure 8b) have confirmed the effectiveness of the bar grouting obtained with structural fluid mortar, and the value of adhesion strength between bar and injected masonry has been evaluated for the final structural design.

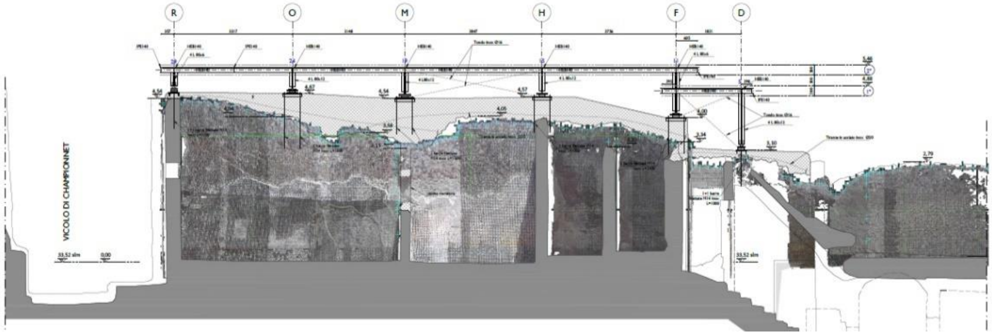

Figure 12. Executive section with cover, supports and walls.

3.8 Roofing made with Corian slabs

The use of "Corian®" plates for the realization of the covering mantle is a new application. The Corian® is currently used for the construction of facades of buildings. For this reason, the structure necessary for the connection of the covering layer (the extrados and the intrados of the metallic carpentry) has been the object of laboratory investigations to verify their resistance during the operating phase and in the rare load conditions, such as the future maintenance phases. Figure 12 shows the test design and the execution of the laboratory test on Corian® slabs.

(**a**)

(**b**)

Figure 13. The laboratory testing on Corian® slabs upper and bottom surface (**a**) the test in laboratory, (b) the test on the connection of the slab.

3.10 Structural analysis results

The design of the new structure has been made modelling the structure with a spatial finite element model, using a commercial software NOLIAN. A linear static analysis, a modal dynamic analysis and analysis with response spectrum have been performed according to NTC2008 (Italian code). The spatial model of the two roofs is shown in Figure 14.

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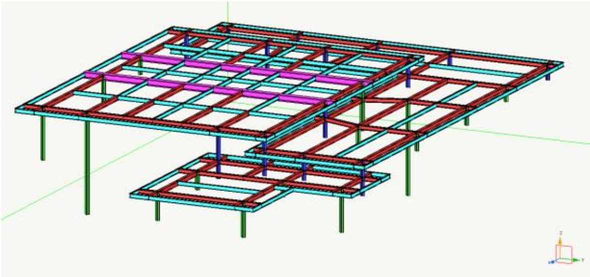
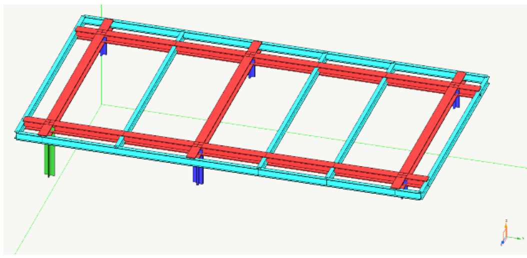


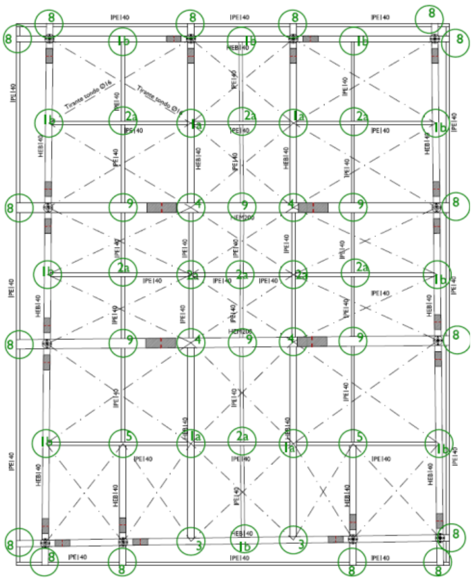
(a)



(b)

Figure 14. The structural models of the roofs (a) and (b).

At the base of the columns the bearing device are modelled with elements having the stiffness of the Elastofip 1.5EF 7.2. The structural detailing (Figure 15, 16 and 17) is designed according to NCT2008. The masonry walls have been verified locally on the bearing according to Eurocodes and against overturning mechanisms according the limit analysis [16]. Figure 15 shows the structural design of the details, while Figure 16, 17 the structural elements on place during construction.



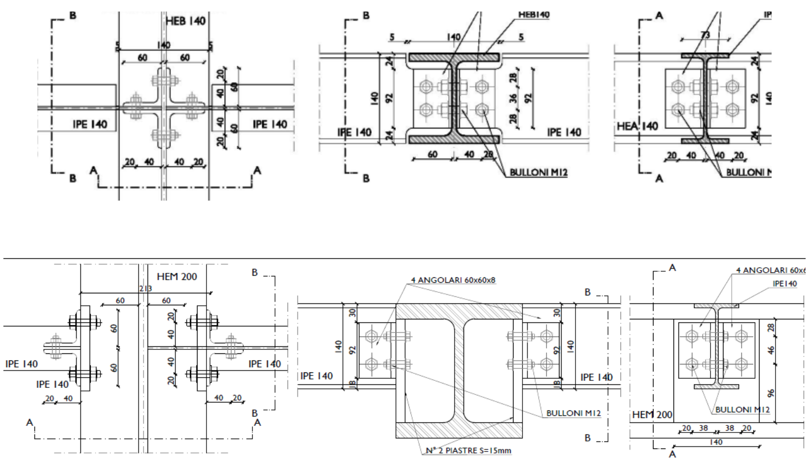


Figure 15. Structural design and detailing of the roofs

(a)

(b)

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Figure 16. (**a**) Steel slab detail; (**b**) steel rob detail.

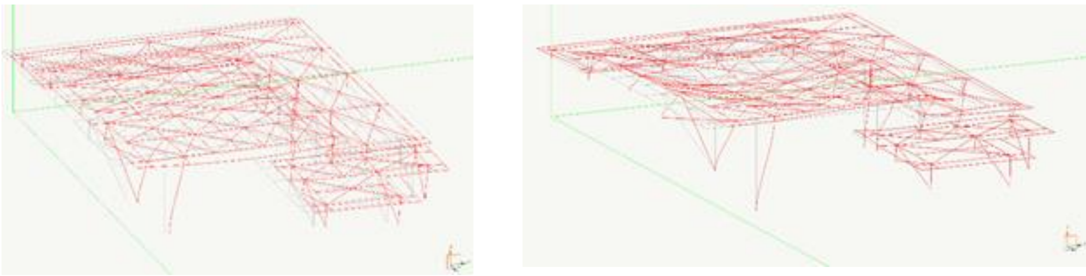
(**a**) (**b**)

Figure 17. (**a**) Steel beams during structural work; (**b**) details under construction.

3.10 Efficiency analysis

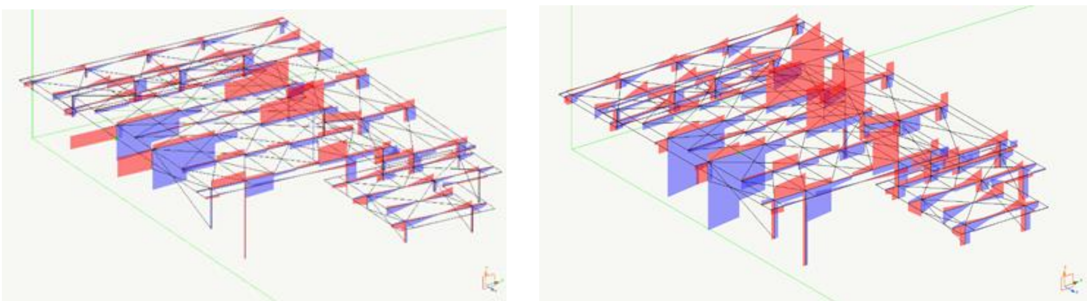
The efficiency of the structural designed is performed. In the following a comparison between the isolated structure at the base and a fixed base structure (the same structure modelled with interlocking constraints at the base) is presented, in order to show the benefits induced by the rubber bearing device installation, in terms of shear stresses at the columns base and at the top of the underlying walls. First, introducing the bearing devices a shift in the first natural period of the structure is registered, the first modal shapes are compared in Figure 18.

The result comparison shows a 424% reduction in shear in the base isolated structure (see Figure 19 and Table 5)



(**a**) (**b**)

Figure 18. First modal shape: (**a**) isolated structure, (b) Fixed based structure



(**a**) (**b**)

Figure 19. Comparison in terms of shear (**a**) base isolated structure; (**b**) fixed base structure.

Table 5. Maximum shear comparison

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column n.	Element	Comb	Maximum Shear V[daN] Base Isolated Stucture	Maxuimum Shear V[daN] Fixed base Structure
9	4L80x6	20	1362	1813
12	4L80x12	29	823	4313

4.Conclusions

A conceptual design approach for archaeological settlement has been proposed and applied in the ancient Pompei, where the minimum intervention principle and the need of conservation the historical fabric are of priority importance as well the structural safety. The structural safety and the code requirements need to be reached with a more complex design procedure, that accounts for an exhaustive knowledge of materials properties and structural details. This can be reached with an iterative but rigorous design approach, that considers new technologies for masonry repair and seismic protection, and uses experimental and analytical checks of the obtained structural results. This approach has been applied in the design and construction phase of a restoration works in an ancient aggregate of houses in Pompeii.

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