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Survey and preservation of an abandoned archaeological industrial site

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Abstract
The sites identified as "Industrial architecture" are a collection of structures, having a peculiar identity, which can still be used as a contemporary resource, worth being re-interpreted by means of urban projects of integrated and sustainable transformation urban font. In particular it is necessary to reactivate or create new processes, both production and fruition, supported by an adequate project structure. This is needed to produce architectural and landscape solutions that can match the problems and needs prompted by a territory needing profound transformations, both from a social and economic point of view, by the demand, for environmental sustainability, thus discarding the indiscriminate use of territories. In this framework surveying and reconstruction of the spaces, of the tower and the buildings of the case-study of a furnace along the Lazio coast, are the first part of a larger urban renovation and reconstruction project saving the memory of the original structure.

I. INTRODUCTION

Industrial Archeology is a specialized sector of archeology for studying the evidences attesting how industrialization developed. Being tangible and intangible assets, sites of Industrial Archaeology are extremely different between them including both the real structures, as the abandoned factories, and the plant collection, machinery, images and products.

Then the field of industrial archaeology incorporates a range of disciplines including archaeology, architecture, construction industries, engineering, historic preservation, museology, technology, urban planning and other specialties, in order to put together the history of past industrial activities. The scientific interpretation of material evidence is often necessary, as the written record of many industrial techniques is often incomplete or absent [1,2]. Industrial Archaeology includes both the examination of standing structures and sites unearthing from excavations [3,4]. Industrial archaeology covers a wide range of topics, from early ironworks and water-powered mills to large modern factories, as well as ancillary sites and structures such as worker housings, warehouses and infrastructures.

Industrial architecture topics generally fall into one of the following four categories:

extractive (also known as "basic materials", which includes mining, quarrying, petroleum, lumbering, etc.);
manufacturing (mills and factories, including their power systems and machinery);
public utilities (water, sewer, electricity, gas, etc.);
transport (canals, railways, roads, aviation, bridges, tunnels, etc) [5,6].

The work of industrial archaeologists has led to a greater public awareness of the industrial heritage, including the creation of industry museums and the inclusion of sites on national and international historic cultural registers in several areas of the world. Notable examples include the Ironbridge George Museum, in England, Engelsberg Ironworks, in Sweden, and Lowell National Historical Park, in USA. The Great Britain was one of the first country where the field of industrial archaeology developed during the 1950s, but in the 1960s and 1970s, with the rise of the national cultural heritage movements, industrial archaeology grew as a distinct form of archaeology, with a strong emphasis on preservation, first in Great Britain, and later in the United States and other nations [7].

In Italy some examples of important industrial abandoned sites are the, in the Sardinia island, the *Argentiera Mining Center*, one of the lead and zinc deposits of the region, exploited since Roman times, in use till when the exhaustion of the vein made the activity cease. Other examples in Italy are the *Colline Metallifere* in the Grosseto area specialized for centuries in the extraction and processing of iron and the cast iron foundries, ex Ilva. Sited in the first half of the nineteenth century in Follonica, *Colline Metallifere* became the most relevant iron and steel center in Tuscany. Finally the *Fabbricone* of the Koessler & Mayer Society in Prato, represented a great industrial area of foreign ownership at the end of the nineteenth century. Despite the widespread redevelopment of the areas, it is known that Prato still hosts today, a significant industrial textile district and some of the most important museums of the town are dedicated to the industrial archaeology.

From the seventies to the present, an increasing focus on the preservation and enhancement of industrial assets has gradually developed, also thanks to the identification by UNESCO of a number of production sites that have been designated as part of world heritage. Currently 37 sites in Europe have been identified, of which only two are located in Italy [8]. However, in spite of this there have been few cases of truly virtuous regenerations, characterized by several valueless developments, which have often destroyed the essential features providing the landscape its identity[9].

The illustrated case-study is represented by the abandoned Sieci-Minturno furnace, in the Southern Lazio, a site that still preserves its charm due to its position overlooking the sea, thanks to which it is known as "the cathedral of the sea".

II. CASE STUDY: SURVEY OF THE SIECI-MINTURNO FURNACE

The archeological industrial complex, with its characteristics and peculiarities, has a strong impact and an extraordinary identity which must not be dispersed.

The structures and the so-called "funnel" smokestack, of the Sieci brick factory, also called furnace of Scauri-Minturno, inactive since 1982, represent today an example of industrial archaeology; it had a typical oven for firing bricks, invented by Friedrich Eduard Hoffmann, operating continuously.

The former factory, with its impressive warehouses, a chimney and a long pier on the sea, actually inexistent, was created in 1880 by a company from Florence, on the model of the original factory in Pontassieve. The factory produced Marseilles bricks and tiles which were also exported to South America by sea.

In a first idea of urban regeneration, a project of reconversion has been proposed to turn the site into a polyvalent structure destined to host, among others, a museum center, a swimming pool and a bio-marine laboratory. It is indubitable that this precious asset of the city of Minturno should be rehabilitated with a view to relaunch tourism and to create new entrepreneurial precincts, while paying constant respect to the history of its previous generations. At present, the site is located in a state of poor preservation and neglect, with its structures modeled in Romanic architectonic forms built of stone, brick and reinforced concrete devoid of any fencing.

On these premises, the first step has been the topographical survey of the area Fornaci Sieci, situated in the municipality of Minturno in the province of Latina, extending on an area of about 4,600 square meters, located, from a cadastral point of view, in plot n°25 of folio 33 of Minturno.

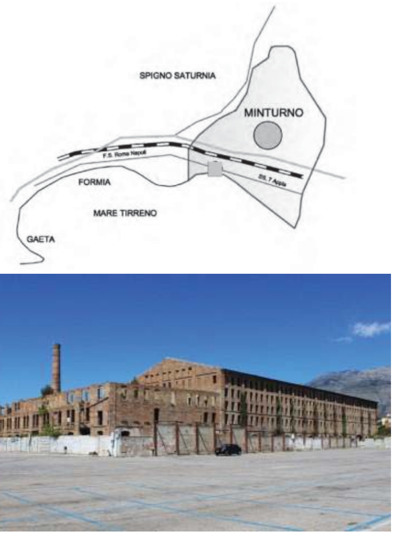

Fig. 1. Localization and view of the site

This plot is oriented to the North-East, along the direction in which the area of Fornaci-Sieci is limited by the Via Appia on the north side, where the only point of access is available, and by the seafront of Minturno on the south side (Fig.1). The buildings existing in the area are represented in the state-of-the art floor plan displayed in figure 2, and are numbered from n° 1 to n° 9 (Fig.2). For each of them, as well as the building n° 17, bases have been drawn and the volume calculated. The aforesaid buildings, formerly dedicated to the brick factories furnaces, are now derelict and partly collapsed, especially those characterized by sloping roofs.

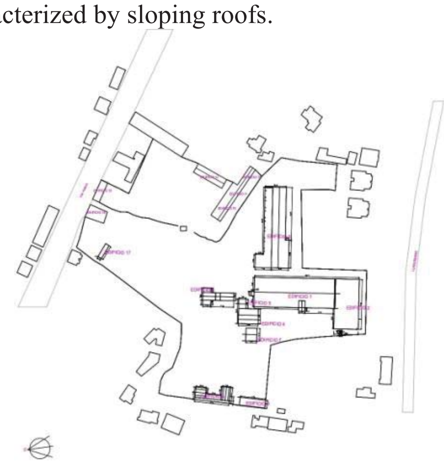

Fig. 2. Distribution of buildings in the area of the Sieci furnace

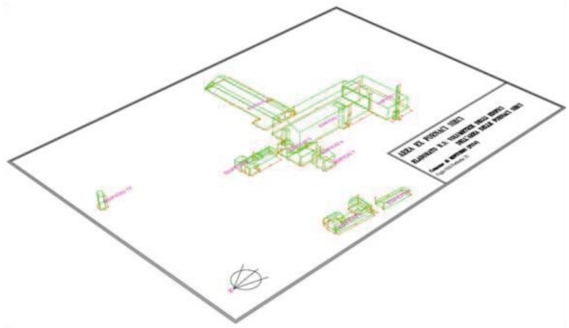

Fig. 3. 3D view of the buildings in the area

All buildings are made of masonry, and some of them, as buildings n° 6 and n° 8 have vaulted roofs. In particular building n° 8 is better preserved as a result of a previous intervention of restoration and has been object of a structural analysis of its roofing, using an innovative method to calculate the thrusts on the walls sustaining the vault.
That is a method of structural analysis, to be described in the next section, particularly suitable for modeling vaults as a discrete network of ribs, subjected only to forces of compression, balanced by the gravitational forces.
From a topographical point of view, the whole survey of the area was inserted in a framing network delimited by 4 fiducial points PF.
The survey operations have been executed with a Leica TCPM 1205 total station having an angle precision of 5'' equivalent to 1.5 milligon and a precision in the measuring distances equivalent to the value of 1-2 mm.
The measurements have required 3 days, 12 station points an about 730 detected points. To these must be added also measurements of further points of which are not within plot n.25, and therefore not objects of specific interest: these are adjacent buildings for which it has been useful to determine the plans and the volume for achieving an overall view of the building stock and the existent objects on the whole area.
The standard deviations of the planimetric coordinates turned out have been of the order of a few millimeters and those of the heights of a few centimeters.
The volumes of the buildings have been calculated from their external plans (Fig.3) and the values are as follows:
Building 1: 36538 mc
Building 2: 10879 mc
Building 3: 5179 mc (considering a total surface of about 1717 square meters, a variable height, culminating at 6.00 meters, and a length and width of about 3 meters)
If we also consider the demolished volume of the whole and if we make the hypothesis of a height of about 3 meters on a area of about 646 square meters we can estimate a final volume of about 1938 square meters for which the overall volume of the building 3 (existent+ demolished) amounts to about 7117 cubic meters.
Building 4: 1900 mc
Building 5: 575 mc (the building situated between building n° 4 and building n° 6 has been surveyed only partially because a large part of it had collapsed and its remaining part is substantially inaccessible. In fact it has been possible to survey only the culminating point of the building and to make on its shape a similar hypothesis of the roofing, so as to enable a summary estimate of the original volume. This estimate has led to a volume of about 575 cubic meters).
Building 6: 1542 mc
Building 7: 1143 mc
Building 8: 1788 mc (considering as a volume the arcade closed on 3 sides and open on the fourth sides.
Building 9: Total volume 781 mc
Building 17: Total volume 259 mc.

III. VAULT STRUCTURAL ASSESTMENT: ANALYSIS AND RESULTS

In order to analyze the structural efficiency of the roofs of some buildings of the complex,, i.e. the vault that covers building n.8, used today as the headquarters of the Regional Park Ulysses Coast, a Thrust Network Analysis (TNA) has been performed (Fig.4).
This analysis can be used to verify that the vault is capable to withstand applied load by means of compressive membrane internal actions with a limited eccentricity with respect to the vault's mid-surface in agreement with the Heyman's principles for the limit analysis of structures made of no-tension materials. These principles can also be extended to materials exhibiting a low strength in tension, like weakly reinforced concrete shells.

Fig. 4. Vault building n.8

TNA model of the vault, of plan size 10m x 10m, is a network of 10x10 meshes whose nodes are positioned along an orthogonal grid of spacing 1m x 1m, see, e.g. the following figure (Fig.5). Here, the limit values for the vertical position of nodes is represented by the dotted lines. These limits have been evaluated as a function of the vault thickness and geometry.

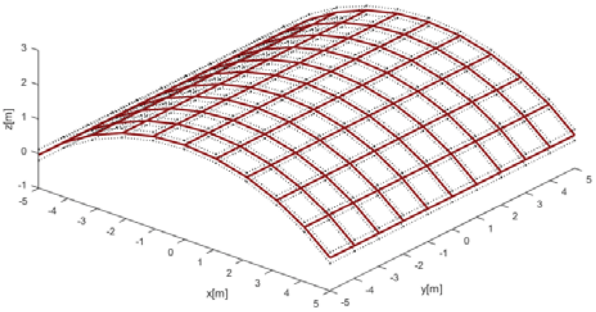

Fig. 5. TNA model vault

Each node is loaded by vertical forces corresponding to the vault's self-weight, evaluated by considering a weight per unit volume of concrete equal to 25kN/m3 and associating a volume of 1m x 1m x 0.25m to internal nodes, 1m x 0.5m x 0.25 m to side nodes and 0.5m x 0.5m x 0.25m to corner nodes. Accordingly, vertical forces at nodes are equal to fz=6250N for internal nodes, fz=3125N for side nodes and fz=1562.5N for corner nodes.

In the numerical procedure, the minimum thrust has been assumed equal 1 for branches parallel to the vault's axis and to 100 for branches orthogonal to the vault axis. Only for the branches on the two sides of the vault a thrust limit of 50 has been assumed. The actual magnitude and units of these thrust limits is not relevant, since their relative ratio is used to drive the optimization procedure. Having higher minimum thrusts in transversal branches, the procedure is driven to find a solution in which the vault works as a series of parallel arches.

Solutions of minimum (deepest) and maximum (shallowest) thrust are reported in the figures 6 and 7. In these images the thrust values are represented by means of a colour legend in which blue shades are associated with lower thrust and red shades with higher thrust. From the figures 6 and 7 it is visible the different value of thrust associated with the two solutions and with each set of branches (longitudinal, internal-transversal and side-transversal). It is also apparent a boundary effect generated by the lower value of thrust and loads associated with the front and rear sides of the vault.

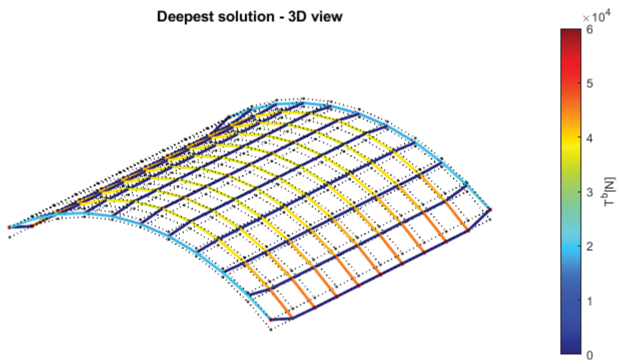

Fig. 6. Deepest solution - 3D view

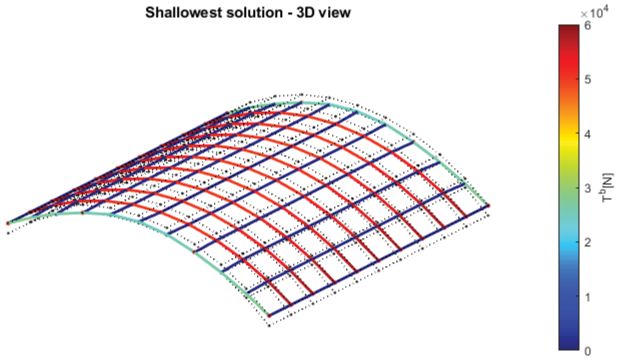

Fig. 7. Shallowest solution - 3D view

In order to better represent the thrust network configurations corresponding to the deepest and shallowest solutions, we report also two cross sections of the vault. In particular the deepest configuration of the thrust network is tangent to the vault's extrados at the crown and touches the intrados at springers (Fig.8). The opposite happens for the shallowest configurations, for which higher values of thrusts are computed (Fig.9).

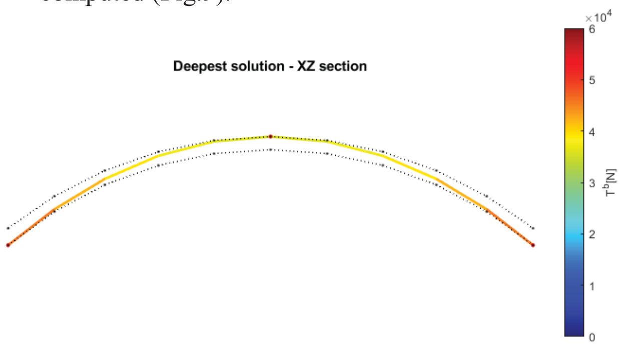

Fig. 8. Deepest configuration and thrust values in a cross section

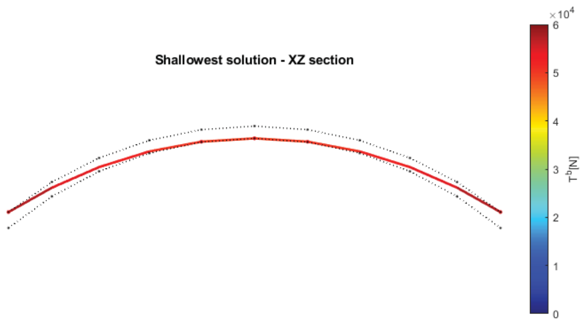

Fig. 9. Shallowest configuration and thrust values in a cross section

It has been shown in [10] that an estimate of the geometric safety factor of the vault can be obtained by evaluating the ratio Rs/Rd, between the scaling parameters associated with the shallowest and deepest configurations of the thrust network. For the present

vault, subjected to vertical loads, this ratio has the value 0.72. This means either that the vault's thickness could be safely reduced to a lower value or that the vault is capable to withstand a wider range of loading conditions.
For historic structures, in which a structural optimization is of limited applicability, it is interesting to estimate the limit multiplier of horizontal loads. Actually, this information can be used to estimate the safety factor of the vault with respect to seismic actions. To this end, the thrust network has been subjected to a set of horizontal nodal forces proportional to the vertical ones. The proportionality factor has been increased progressively until the ratio Rs/Rd attained a unit value. This is reached when fx/fz = 0.815, meaning that, if statically applied, the horizontal forces can reach a value corresponding to the 81.5% of the vault's weight. The corresponding deepest and shallowest configurations of the vault are coincident, as shown in the following figures (Figg.10-13).

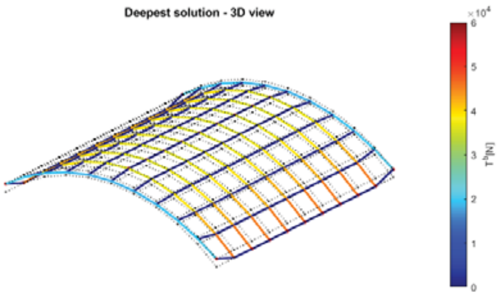

Fig.10. Deepest solution 3D view for vertical and horizontal loads

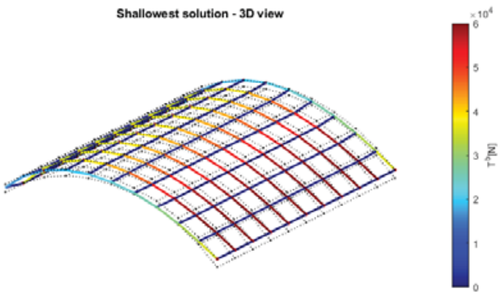

Fig.11. Shallowest solution- 3D vie for vertical and horizontal loads

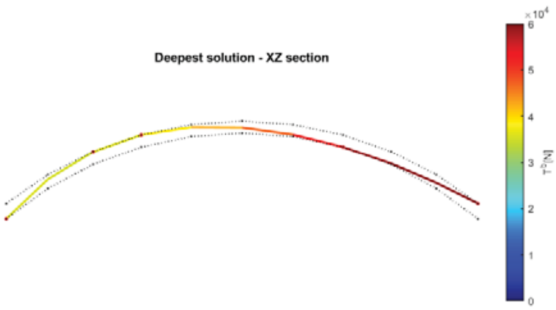

Fig. 12. Deepest solution for vertical and horizontal loads - XZ section

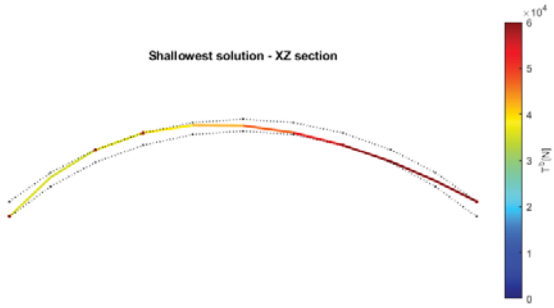

Fig. 13. Shallowest solution for vertical and horizontal loads- XZ section

In these figures, it is shown how the horizontal forces, which act from left to right, produce both a geometric and static modification of the thrust network configurations computed for the vertical loading condition. In particular, nodal heights tend to increase in the left part of the vault and tend to decrease in the right part. The corresponding network configuration is characterized by larger curvatures on the side that is opposing to the direction of horizontal forces. At the same time the transversal branches on the left side of the vault are unloaded, while the leftmost branches undergo thrust increase. When the limit value of the horizontal load multiplier is reached, the deepest and shallowest configurations become undistinguishable and touch the intrados of the vault at the left springer and its extrados both at the centre of the left part and at the right springer.

IV. CONCLUSIONS

The Furnace of Sieci, in the municipality of Minturno, is an example of "rejected sites" or "ruins" disseminated throughout our country which, although if inadequate to accommodate the innovation of new processes, can be seen as an important archaeological resource of the territory if included in appropriate urban, economic, social regeneration strategies.
The Sieci brick-furnace is a symbol of the city of Minturno-Scauri and its restauration could be a first step towards the future revalorization of the site.
The three areas of the still existing industrial site are: the area between the Appia street and the principal part of the furnace, in which the headquarters of the Regional Park Riviera of Ulysses, the Municipal beach delegation, the Pro Loco of Minturno and a Center for the elderly are located; the area between the furnace and the seafront and finally the furnace with the characteristic smokestack. In the wide square in front of the furnace a weekly market takes place while, during other days in the year, the area is used for parking and artistic manifestations.
In 2011 it has been carried out an accurate geomatic survey of all structures of the abandoned industrial site and, later, a safety assessment of the vaulted roof of some buildings of the complex. This aspect has represented a

preliminary step for the urban regeneration of the site, so far never realized, aiming to realize a multipurpose facility containing, moreover, a museum, a swimming-pool and a marine-bio laboratory.

On an area of about 4600 square meters the silhouettes and the geometries of all existing buildings, between those best preserved and ruins, with a total volume of about 60584 cubic meters, have been surveyed. For some of these buildings, most of them made of masonry, the safety of the barrel vault roofs, subjected to the action of seismic forces, has been verified and 3D models created. The adopted method i.e. the called Thrust Network Analysis (TNA) has permitted to determine the thrusts of the vaults subjected both to vertical loads, represented by their own weight, and to horizontal forces, proportional to the vertical ones, so as to simulate represented by the seismic forces. The obtained results of the thrust values, lower in correspondence of the front and rear sides of the vault, and higher at the center of the vault, have permitted to verify that the thickness of the vault can be reduced, while maintaining conditions of safety and resistance to higher load values.

The results of this work are preliminary and useful to promote a process of knowledge of the complex of the Sieci-Minturno furnace, in the hypothesis of a reconversion of spaces and their reuse.

Finally in the chance to experiment processes of re-appropriation and reactivation of the complex, the value of the document that the industries bear imprints on their walls also represent one of the strongest element, of the community identity as well as a testimony of the production process.

ACKNOWLEDGMENTS

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