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Strategy of sustainable development of an industrial archaeology

Giacomo Di Ruocco^{a,*}, Enrico Sicignano^a, Italo Galizia^b

^aUniversity of Salerno, Via Giovanni Paolo II 132, Fisciano 84084, Italy

^bDepartment of Cultural Heritage - Order of Architects of Naples, Piazzetta Matilde Serao, 7, Napoli 80132, Italy

Abstract

“Re-learn” and “Re-value” are the keywords at the base of the sustainable exploitation strategy of cultural heritage, little known but highly cultural and environmental valid, belonging to Southern Italy, already colony of Magna Graecia. The main goals are to “spread” the knowledge of the territory, “enhance” the sense of belonging to a new physical and cultural reality, “develop” the perception of a new metropolitan reality and “promote” the enjoyment of the environment, aiming at a careful and conscious cultural tourism. Within the tourism network, our idea tends to include particularly significant and representative sites of Campania’s history and culture, little known ones such as Campi Flegrei, Sorrento and Amalfi Coasts, Litemum, Nola, Cimitile, Amalfi, Agerola, Gragnano, etc. The present case study concerns, in particular, the Valle dei Mulini (“Mills valley”) in Gragnano, which is an example of proto-industrial archaeology dating back to the twelfth century as well as an old dirt road connecting with Amalfi republic. This site is featured by canals carved into the rocks, which lead water directly to the mills towers, capable of converting the pressure of the hydraulic machine movement into useful energy. More in detail, the sustainable aspect of this project foresees the production of electricity by exploiting the mechanism of the falling water in water towers, giving rise to the grindstone rotational motion which is turned into electrical energy. The water flow passes from one tower to another one, placed at a lower altitude, and then moves on to the next one. Therefore this strategy would enhance the whole ecosystem, by means of site remediation and artifacts restoration, in order to place this resort in the tourism / hospitality circuit and trigger a sustainable process aimed at its future safeguarding.

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* Corresponding author. Tel.: +0039-333-90-40-747.

E-mail address: g.diruocco@unisa.it

1. Valley of the mills of Gragnano[†]

Originally Gragnano consisted of scattered villages of Osca origins. In 89 A.C. there was the first urbanization, because after the destruction of Stabie[‡], accomplished by Silla, its inhabitants took refuge in the territory of nowadays Gragnano. According to a legend, Publius GRANIO, Silla's lieutenant, settled at the foot of Mount Aureo providing protection and support to those who had taken refuge there. These latter, being grateful, gave this land the name of Gragnano. Others say the name Gragnano comes from "*Praesidium Granium*" Gens Grania had got in this area.

From the fifth to the tenth century A.C. the territory was subject to barbarian invasions. In 552 the Lattari mountains area was involved in the battle that marked the end of Goths dominion the in favour of Byzantines, that's why in this period the castle was built with defensive function.



Fig. 1.(a) Fortified complex of Pino and adjoining church (Pimonte); (b) Tower of Massi, Aurano (Gragnano).

In the tenth century A.C. the territory was annexed peacefully, through agreements, to the Republic of Amalfi who armed himself of the castle and Letters of Gragnano to defend his back. The castle of Gragnano and having three walled constituted, with the Castle of Pino (Fig.1a), the Castle of Letters, the Massi tower (Fig.1b), the homonymous bottom of Aurangabad, and the Pimonte castle were the bulwark to the north of the duchy of Amalfi. So Gragnano fell in 1131 in the hands of the Normans[§].

The Duchy of Amalfi, including Gragnano, fell into the hands of the Principality of Salerno. The town was sacked and continuously, until the rise to the throne of Naples of William II, survived as royal property.

In the following years, in order to defend themselves from the continuous plundering of Lombards, Gragnano population took refuge in difficultly accessible places by building villages such as Caprile, Aurano and Castello. Thanks to their good strategic position, these villages dominated from above the road from Stabiae to Amalfi, the actual carriage of the Valley of the Mills (Fig.2).

This territory, rich in waters feeding the Vernotico creek, was chosen for the mills construction.

In Gragnano's Mills Valley, as well as in Amalfi's one, there are vegetation species dating back 10,000 years ago, surviving to a period which can be placed between the last two ice ages. Fern in its various types is the dominant vegetation. The most common is the Maidenhair fern (Fig. 3a), once used for medical potions. The rarest and most famous is the Woodwardia Radicans, identified by botanist Micheli in 1710. Large in size, it can reach a height of 1.80 m and does not reproduce like common ferns by different sex spores but through self-reproduction. A

[†] Elaborated by Italo Galizia

[‡] G.Di Massa, *Gragnano, The ancient Stabiae territory* – Eidos, Castellammare di Stabia, 2005

[§] D.Camardo, M.Esposito, *Le frontiere di Amalfi. I castelli stabiani dal ducato indipendente alla dominazione angioina. Analisi delle fabbriche del castello cattedrale di Lettere*, Edizioni EIDOS, Castellammare di Stabia (Napoli), 1996

bud like a garlic clove is formed on the end of the leaf, making it bend to the ground for its weight, where it plants its roots, giving life to a new leaf.

Today the Woodwardia Radicans thrives in Iron Foundries Valley in Amalfi and in Imbuto Valley, while in Gragnano’s Valley, although present in the past, it has been subject to raids by florists for the composition of funeral wreaths, and by shepherds to wrap fresh cheese. Although it has been spotted in some places reported to the experts, so they await its blossoming in the spring. Among other types of ferns present is the Pteride of Crete Fern (Fig.3b). Wild orchids are also present. A surviving species is also the Pinguicola Hirtiflora (Fig.3c), a small carnivorous plant with a purple cup shaped flower and milky leaves, which trap insects, particularly widespread on Fauto Mountain. The particular enzymes found on its leaves enable the insects digestion and have been used for centuries by shepherds to curd milk. Another survived species is the acanthus plant, used by classical sculptors to decorate the temples capitals (Fig.3d). These plants owe their survival to the particular microclimate of the valley, characterized by a high level of humidity, the abundance of surface and underground water, as well as the temperature uniformity due to its location enclosed in a gorge surrounded by mountains, which protects it from cold winds.**.



(a) (b)

Fig. 2.(a) Valley of the mills in Gragnano; (b) Aqueduct in the Valley.



(a) (b) (c) (d)

Fig. 3.(a) Maidenhair fern; (b) Pteride of Crete Fern; (c) Pinguicola Hirtiflora; (d) Acanthus.

1.1. The mills: historical notes.††

Mills are the material evidence and the historical memory of Gragnano’s productivity, through the signs of their installation and their use until the introduction of the flour tax and energy - first steam and then electric energy - which

** A.Liguori, “Gragnano. Memorie Archeologiche e storiche. Pompei, 1955

†† Elaborated by Giacomo Di Ruocco and Enrico Sicignano

decreed its abandonment. The flour tax, which was introduced after the unification of Italy by Piedmontese people, penalized small mills, especially in the South, because it was paid depending on the millstone turns. The southern and especially the Mills Valley's ones, due to their small size, recorded a remarkable number of turns, detected by a counter placed on the millstone, which inevitably determined the increase of the tax. Subsequently, the introduction of electricity caused the dislocation of factories in the town centre; in fact, many pasta factories were equipped with a mill. Despite the shift from hydraulic to electric energy, which had decreed their abandonment, some of them were re-used due to the suspension of electricity during the Second World War. Since their birth, mills' history is made of steps and mutations between different cultures and parts of the world. The grain mills were probably conceived in the Middle East and were introduced in the Roman imperial era. In fact, for the period around 75 A.C., Plinio the Older writes about their wide diffusion in Italy. The first Roman water mill was a horizontal wheel one, with a vertical shaft transmitting motion to the grind placed over a fixed one, a typology existing in the Valley of the Mills. The principle of the wheel moved by the water force has been known by India inhabitants since the fourth century B.C., but its use in the West has been documented since the second century B.C., as attested by of Vitruvius and Lucretius writings (*De rerum natura*) and the archaeological finds of Barbegal in France and Venafrò.

Vitruvius had described the operation of a hydraulic wheel which he defined "cochlea" because it consisted of tubes made of wood wrapped helically, similar to a shell. Following the collapse of the Western Roman Empire, the decline in the number of slaves made the introduction of mechanical means necessary to replace labour, and thus the spread of the mills began, which turned out to be considerable only after the European rebirth in 1000, when hydraulic power was not only used for grinding grain but also for presses, mills, tanneries, paper mills, spinning mills, fulling mills and lathes. The hydraulic engine favoured the flourishing of crafts and professionals such as the miller, the blacksmith and the pannizzaro, which characterized the life of medieval villages in the twelfth century.

The construction of the vertical wheel mill (called Vitruvian), replacing the horizontal one, guaranteed more revenues because in the horizontal systems each wheel moved a millstone directly without other gears, consequently each wheel turn corresponded to a millstone round; instead in the case of vertical wheel mill, each wheel spin corresponded many millstone laps. Their origin dates back to the first century B.C., as evidenced by an epigram of Antipater from Thessalonica: "*women employed in grinding corn, you can sleep as long as you like ... Ceres is ordering Naiads to do what your hands did: they obey, they rush up to the top of a wheel and spin an axis; by means of the rays that surround the axis, it violently moves acted millstones*". Strabo wrote about a water mill that Mithridates had built in Cabiria in 65 B.C., neighbouring his new building, the oldest one which has been documented.

1.2. The mills: typology, functioning and use ^{††}

The water mill is set up as a highly sustainable, ecological and economic preindustrial artefact, as it saves the resources that would have been used for its operation if it had been driven by animals or humans. The presence of a water wheel in Gragnano's and Amalfi's Valleys of the Mills is possible thanks to the presence of a rich and detailed hydrographic network and its orography. The typology corresponds to the simplest type, the horizontal wheel one, a prerogative of the peasant societies which were less developed and managed by a quite weak central authority. Such a simple technology required the realization of accessory structures that favoured the operation of the hydraulic engine: in order that the water jet could impart a motion to the horizontal wheel and then to the other gears connected to it, water had to be channelled through a series of fundamental structures such as aqueducts, archi-channels, water towers, and creating a symbiotic relationship with the surrounding territory, both when it was changed and when it was turned. Through a feeding channel of a minimum slope, the water picked up upstream of the mill was poured into a water tower sometimes connected to a second one, which had the function of an energy reservoir. The feeding channel, usually short in order to reduce construction costs, presented a minimum slope and was directly built into the rock or on the ground, through a system of aqueducts (Fig.4a). The used material was calcareous stone, as well as the tuff present in large quantities in underground caves. To prevent water leakage into the tuff stone, the interior of the canal was covered with a mixture of lapilli or terracotta tiles. The building,

^{††} Elaborated by Giacomo Di Ruocco and Enrico Sicignano

rectangular in its shape, had thick outer walls and a vaulted ceiling of Arabic origins. The architectural structure is divided into two levels: a ground floor consisting of a single room for processing where the millstone was located (Fig.5a) on a mezzanine floor, and a lower floor, a vaulted room said “prison”, occupied by the water wheel (Fig.4b) directly contacting the water coming from the free-fall well (water tower), the windmill generator real system^{§§}.

There are also mills with a flat cover as “La Pergola” (Fig.5b) in Castle street or with a roof, as the mills in Via Serbatoio, in Caprile. Due to the regime of Vernotico creek which was variable in time and space and the presence of debris, the channel hydraulic flow toward the tower was governed by simple wooden locks (Fig.5c), placed on the access to the tower itself. The water tower, through a conically sectioned wooden nozzle, and with its top towards the wheel, led the deposited water directly on the blades of the wheel placed horizontally in the prison, a space below the mill itself. The pressure energy, directly proportional to the height difference between the nozzle and the water free surface (hydraulic head), was turned into kinetic energy able of running the driving wheel. The water – with no waste - escaped through a landfill in the stream below (Fig.6). In the Valley there is also a typology of cascade mills, where the mill above fed the one below, which is currently not visible, because it is completely covered by vegetation. Functioning through a vertical axis, the wooden driving wheel was made integral with the two millstones, one fixed at the bottom with grooves and a lighter upper movable. It was usually used the molar stone of San Giuliano quarries in Molise because it consists of a limestone matrix with quartz fragments which gave it the dual characteristic of hardness and workability for the joints needed to the positioning and the grooves that enabled the ground wheat, flour or semolina, to scroll to the outside for its collection. It was sometimes also used basalt stone of Cascano quarries near Caserta. It took two hours to fill the sack located next to the mill’s upper floor, as the operation was repeated seven times to get the grain heart containing gluten. The preceding steps allowed to derive other substances, such as bran and cruschella (“little bran”), to be given to animals. To avoid the wear due to friction at the base of the axis fixed to the driving wheel and the movable grinding, they used hardwood and lubricated the shaft end and the bearing on which the axis rotated by fat.



(a)



(b)

Fig. 4.(a) Arco channel built into the rock; (b) Water wheel underground iron, because it is more recent. It was once in the wood.

A system of levers operable from the outside allowed small displacements of the movable grinding to prevent or decrease the friction between the latter and the fixed one. On the movable grinding top and coaxial to it, a loading hopper was fixed where the grist was pumped in which, through side channels, flowed into the gap between the mobile grindstone and the fixed one. Ray-shaped grooves, made by skilled artisans, led the flour or semolina

^{§§} C.Sicignano, *La Valle dei mulini di Gragnano (Na) da luogo della memoria ad ecomuseo, quale ipotesi per uno sviluppo sostenibile*, in *Ambiente, Costumi, Costruzioni*, scritti in memoria di Sergio Bonamico; a cura di A.de Marco e G.Tubaro, MIMESIS / Architettura (Milano-Udine) 2012

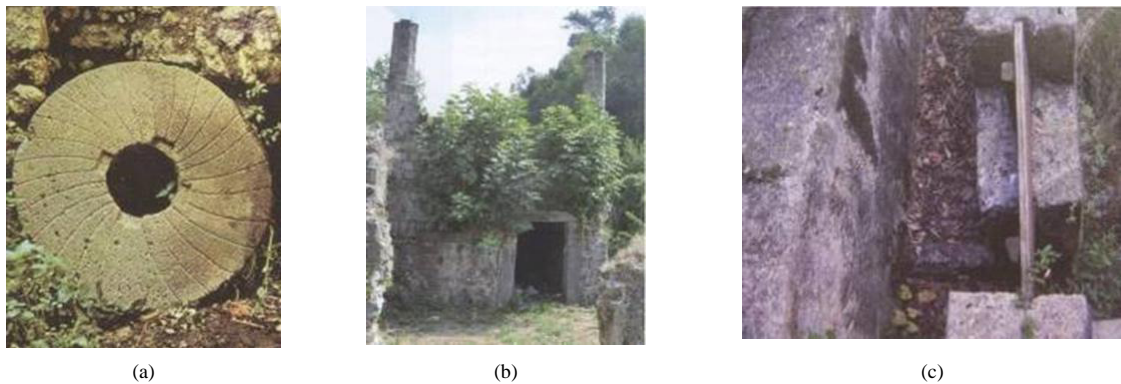


Fig. 5.(a) Millstone fixed with grooves to allow the ground escape; (b) “La Pergola” Mill; (c) Bulkhead or locks of diversion of the channel.

outwards. The mill in question, which has two stone wheels of very hard material, one fixed and the other rotating above the first, is also defined as millstones finisher (fig. 9b). The material is fed in the middle of the sprayer and forced to pass between the surfaces of the two wheels, undergoing breakage by compression and cutting. The wheels surfaces are crossed by grooves and the ground material goes out radially. The millstones mill is among the oldest types of mills and is widely used to grind seeds, pigments, colours, cosmetics, and pharmaceuticals.

The windmills were mainly used for grinding wheat for durum production and soft wheat for flour production. In 1764 approximately 2,000,000 wheat *tomolos* were ground along the valley, equal to about 1,100,000 quintals. In numbering the Fires of 1641 in Gragnano there were 23 millers and one pasta maker. Fires were a kind of the population census of Universities or local government, which was used for the payment of a tax corresponding to three pugs for each fire. According to historian Matteo Camera, the Valley of the Mills hosted fulling mills, machines used for fulling wool tissues and equipped with hydraulic wheels that exploited the wealth of water present in Gragnano’s Valley of Mills. The flourishing of these arts, in addition to those of the leather and silk tanning (silk being supplanted during the eighteenth century because of a disease that had haunted mulberry trees plantations with which silkworms are fed), was permitted by the favourable climatic conditions, the abundance of water that provided water power and the proximity to Amalfi, on which Gragnano depended during the flourishing years of the amalfitana republic. According to tradition, in fact, Amalfi masters of the white art took refuge in the twelfth century on Gragnano heights to escape Norman invasions, planting their activity - acception collected by contemporary writer Maria OrsiniNatale in her novel “Francesca and Nunziata”^{***}, although set in a later period.

Thanks to its relationships with the East, Amalfi people introduced cutting-edge working techniques, which favoured the installation of windmills for grinding grain and numerous factories for processing paper, iron and clothes on a large scale, in the homonymous Valley of Mills on Amalfi side, crossed by Canneto river, and in the above-mentioned ones. In fact, almost all of the milling potential of the city of Naples was concentrated in two main areas: one on the Salerno coast in the area between Amalfi and Vietri; another one in the area between Gragnano and Torre Annunziata. In two documents Faraglia mentions the milling business of Castellammare (to be considered as a whole with Gragnano), the first dating back to 1476, which mentions that the grain purchased was ground in Gragnano’s, Torre Annunziata’s and Vietri’s mills, the other dating back to 1653, when the Duke of Guise, once occupied Castellammare and took control of the mills, forbade to grind the fodder for Naples supply.

Gragnano’s milling business is also attested in two calls: one dating back to 1568, when it was established that “when bakers needed to send the wheat to be ground to Castellammare, Gragnano and Scafati, the output of grains from the city and the entry of deriving flour had to take place solely through Naples’ small pier’s customs to prevent smuggling and tax evasion”. The other, in 1713, was interested to vaticali (in the countryside buyers of grain and

^{***} M.N.Orsini, *Francesca e Nunziata*, Avagliano, Salerno 1996

other foodstuffs provided with specific authorization). In particular, it was made official the qualitative difference between soft and durum wheat: the first one, suitable for bread-making, could not be ground in Gragnano's, Castellammare's and Torre's mills, which instead were suitable to hard wheat grinding, destined to pasta production. In 1800, Gragnano became an industrial hub of "White art" boasting the presence of more than one hundred pasta factories.



Fig. 6. "Porta di Castello" mill.

2. The restoration of the mill^{†††}

The philosophy is to completely leave intact mill in its form and texture, restoring the original openings, by similarity with other mills and 800's drawings (Fig. 7, 8). The project involves the complete removal of lapil-concrete blocks, a recent work, and the restoration the limestone masonry, recovered at the site. A double doors gate will be installed, made of cedar wood, with wooden top lintel (recovered from old artefacts demolition); above the lintel a window with chestnut wood and iron grating will be put in place. On the side prospectus we expect to restore the limestone gap and to lay another window, similar but larger than the one on the front door. The project also includes the reconstruction of the hydraulic machine (Fig. 9,10), according to the old scheme of operation, the mechanism of which will be driven by a flow which provides for the recovery and reuse of water; so tourists will be able to pick their own souvenirs of ground corn as they did 1,000 years ago.



(a)

(b)

Fig. 7. "Porta di Castello" mill: restoration hypothesis (rendering).

^{†††} Elaborated by Italo Galizia, author of the project drawings

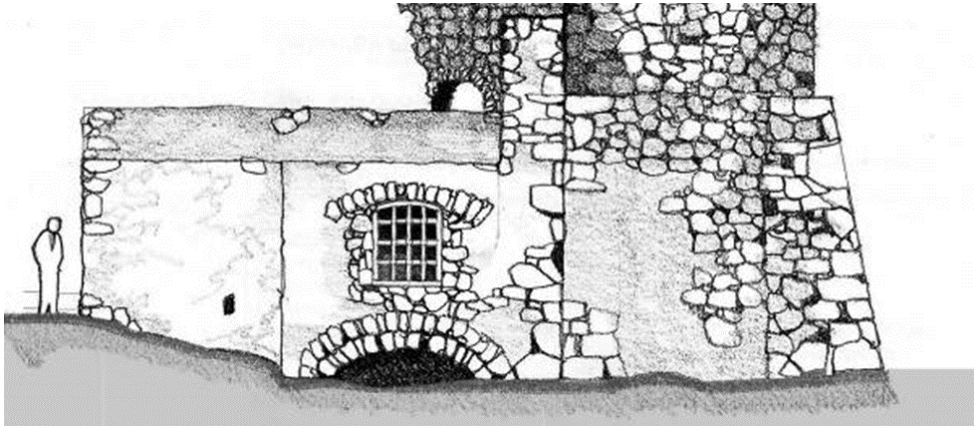


Fig. 8. “Porta di Castello” mill: restoration hypothesis (drawing).

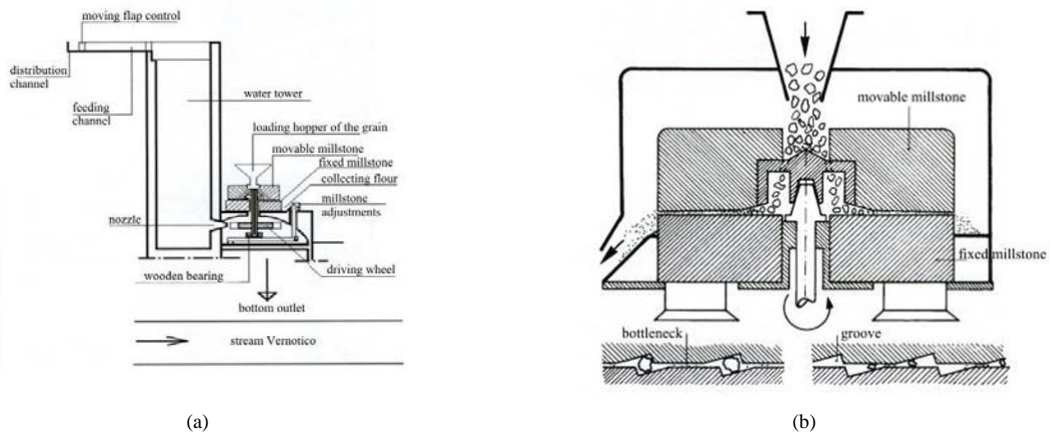


Fig. 9.(a) Mill functioning; (b) Millstone.

3. Sustainability of the project ^{***}

The sustainability of the project will be achieved through the following actions:

- for the recovery of the structure and the recovery of the missing elements, will be used stone blocks found on the site;
- the grindstones of the mill will be handled by the flow of water from the water tower, which will collect rainwater. The water used will be recovered and returned to the tower / pit;
- the energy needed for pumping water and night lighting will be guaranteed by a small photovoltaic system, installed on the roof of the block of toilets, which will be installed in the garden behind the mill;

^{***} Elaborated by Giacomo Di Ruocco

- the management of the mill will be financed from tourist visits to the site and from the sale of small packs of wheat produced in the mill itself.

The Italian GBC (Green Building Council) introduces the concept of sustainability including with regard to the restoration work on the historic heritage. The goal is to change our way of thinking towards the ancient buildings, no longer be exempted from the reflection on energy conservation and the sustainability of conservation action, but to accompany the critical historical debate, necessary and indispensable before any restoration, with a series of assessments of the environmental effects that every choice may entail. The protocol drafted by GBC Italy, is based on a scale with a maximum of 110 points, which allows you to split the interventions that will choose to undergo evaluation in four categories; basis from 40 to 49 points, 50 to 59 silver, gold from 60 to 79, platinum by 80 points up. The evaluated parameters affecting all aspects of life of the building; the site in which it is placed, the investigations to which it was submitted, the design, construction and operation. The GBC specifies what are the requirements for placing the project within the Historic Buildings category, which includes not only the acknowledged housing and protected by superintendents, but all the buildings that are located in the historical era ended, fixed as the previous industrial age, conventionally finished in 1945. Even the building envelopes made after this date will have access to the evaluation, whether they will be able to demonstrate pre-industrial characteristics for at least 70%.^{§§§}.

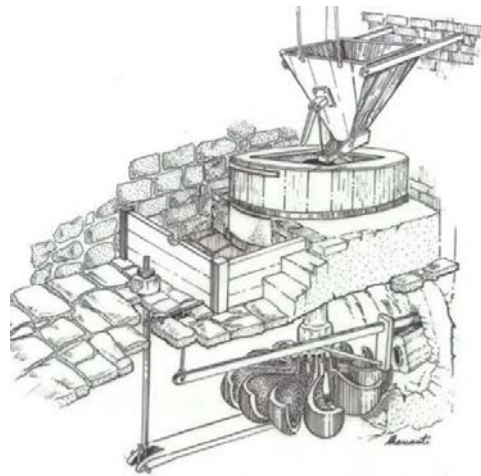


Fig. 10. Isometric reconstruction of hydraulic machine.

The project in question is possible because the structure (both the mill that the adjacent land) has been granted a free loan to the association *Centre for Culture and History of Gragnano and Lattari Alfonso Maria di Nola*, chaired by Giuseppe Di Massa Professor, for years engaged in the valuation policies of the Valle dei Mulini, and the same is in favor of such action.

4. Conclusion ^{****}

The restoration project of “Porta di Castello” mill is part of a strategy of urban and environmental rehabilitation on a large scale. The geographical location of the structure is a strategic part of a green path, which through

^{§§§} GBC Historic Building. Protocol for the rehabilitation of historic buildings (<http://www.gbitalia.org>)

^{****} Elaborated by Giacomo Di Ruocco

Gragnano Valley of Mills, connects Sorrento coast with the Amalfi coast.^{††††} In fact, the overall project will feature a greenway that connects Pompeii and Herculaneum archaeological sites.^{††††} with the Amalfi coast (the “gods’ path” westbound and the “iron foundry Valley” eastbound), Fig.11.



Legend:






| | |
|---|---|
|  | Railway line Castellammare di Stabia-Gragnano |
|  | Intermodal exchange Naples-Sorrento |
|  | Trek Valley of Gragnano-Agerola Mills |
|  | Gods's Path |
|  | Iron Foundries Valley Reserve |

Fig. 11. Overall project, to large-scale.

The project is based on eco-sustainability and environmental criteria, by recovering and reusing existing structures, along the way (mills, railway stations, etc.) avoiding further land consumption.^{§§§§} The greenway will be divided into segments of different nature: the stretch Pompei - Castellammare di Stabia will be through the already operating railroad; the stretch Castellammare di Stabia - Gragnano will be through the restoration of a disused railway track by a hybrid mechanism (diesel-electric) shuttle; the stretch Gragnano-Agerola (through the valley of the mills) will be through with a pedestrian trekking path (already reported by the Italian Alps Committee), which

^{††††} V.Aceto, *Disused railways: Railway Gragnano, Yesterday, Today, Tomorrow*, Thesis in Technical Architecture University of Salerno - Department of Civil Engineering, tutors: Enrico Sicignano, Giacomo Di Ruocco, Fisciano (Salerno), 2016

^{††††} D.Camardo, *Archaeology and conservation at Herculaneum: from the Maiuri campaign to the Herculaneum Conservation Project*, in Conservation and Management of Archaeological Sites, vol. 8 , pages 205–214, 2007

^{§§§§} G.Di Ruocco, E.D'Andria, *Infrastrutture ferroviarie dismesse. I casi di Velia e Salerno-Mercato San Severino*, Centro Servizi di Ateneo, Fisciano (Salerno), 2016

will allow you to enjoy the natural and protoindustrial architectural beauties already described above; from Agerola the path continues towards Positano (in the east) across the gods' path, and towards Amalfi (in the west) across the iron foundries street; both trekking paths are already traced in the trail maps. Within this large scale project, the restoration of "Porta di Castello" mill, situated along Gragnano's valley of mills, plays a decisive role as a tourist attraction and a flywheel of economic development of the territory.

The goal is to re-discover and then re-promote little-known cultural sites of Campania, whose culture is steeped in history, from colonial times of Ancient Greece (500 BC), the Roman Empire (200 BC - 300 AC), to get to the duchy of Amalfi in 1000 AC, in order to expand the tourist offer that to date stops at destinations and the traditionally well-known sites.

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