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Technological performances upgrading and rehabilitation of building heritage inside the historic centre of Palermo

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Abstract. The recovery of building heritage through the containment of carbon emissions is one of the strategies pursued by the city of Palermo. This design approach becomes more paradigmatic when it's referred to sensitive and historic buildings or urban areas, having an international interest or involved in participatory projects for the Mediterranean city, well beyond the attention that citizens attest to them. We would analyse the *Volta* electrical Power Station, inside the harbour area and near the *Castello a mare*, interested by the overall rehabilitation of Palermo waterfront. This building qualify itself, through a retrofit hypothesis proposed by the authors of this essay, as a significant example of rehabilitation design, capable to respect memory but also to propose an improvement of energy performance, through a compatible and technological implementation that use information technology in order to verify passive strategies for internal environmental comfort, an improvement of healthiness and quality of confined environments through high-tech plant engineering choices. The results of this study is a design proposal of a system of openings and an evaporative cooling, contributing to lower the internal temperature during summer.

Keywords – Palermo's electrical power station; rehabilitation of traditional building heritage; energetic performance upgrading; architectural sustainability.

1. Introduction. Sustainable strategies for Palermo and approaches to compatible rehabilitation

The European Commission's initiative for the new *Green Deal* affects the construction sector with the so-called *Renovation Wave*, which aims to rehabilitate millions of buildings in Europe over the next decade. Its objectives are clear: to boost our economy in a period of rehabilitation, improve the quality of life in citizens' homes and, collectively, move towards the goal of climate neutrality by the year 2050. The building sector is the largest consumer of energy in Europe [1]. The recovery of building heritage through the containment of carbon emissions is one of the strategies also pursued in the city of Palermo.

This design approach becomes more paradigmatic when it's referred to significant and historical buildings or urban areas, having an international interest or involved in participatory projects for the Mediterranean city, well beyond the attention that citizens attest to them.

The use of buildings accounts for 36% of CO₂ emissions and 75% of the park built is highly inefficient, because it was built before the energy regulations, and most of them will continue in service in 2050. These data more than justify the commitment of the EU, but a rehabilitation intervention will also entail improvements in other aspects such as the structural safety of buildings, comfort, accessibility and the creation of jobs that are so necessary in the difficult times that we are experiencing.



The recent Italian legislation on energy performance and building efficiency derives from *EU Directives 2018/844*; the transposition of the long-term community strategy, in order to obtain a de-carbonised and energy efficient real estate park by the year 2050, is transposed into the *Integrated National Plan for Energy and Climate (PNIEC)*, structured into five lines of intervention (de-carbonisation, energy efficiency and security, development of the internal energy market, research, innovation and competitiveness). The range of incentive interventions also has been expanded; these incentives are possible using solar thermal systems, heat pumps, geothermal systems, biomass systems, replacing existing and obsolete energy systems, introducing thermal insulation interventions of the vertical and horizontal opaque surfaces affecting the envelope with an incidence greater than 25% of the gross dispersing surface of the building. The main tools that promote the use of renewable sources are already operational. It is the so-called *Ecobonus*, a tax deduction applied to income tax, with a deduction of 50%, 65% according to the intervention and of 110% if there is an improvement of at least two energy classes, paid in 10 years.

The paper shows the preliminary studies for a new approach, typically used in the architectural design of a new building, that can be useful also for the traditional and historical construction.

The particular location of the *Volta* electrical power station in Palermo has required a careful planning for the resolution of that problems related to high temperatures and humidity. According with this purpose, strategies, technical elements and building materials are employed to conciliate the requirements of sustainability and energy savings provided by the actual rules, in order to retrofit the studied *Volta* power station that should be *nearly Zero energy* or, at least, energy auto-sufficient.

As demonstrated by some past architectural and settlement references, the re-evaluation of some environmental aspects starting from the design phase, through the orientation of the buildings with respect to atmospheric agents, the internal distribution of spaces and the mechanisms for opening and regulating flows air and solar radiation, can favor internal microclimatic control without the aid of technological cooling systems, also well guaranteeing the good architectural integration of all those building elements and devices functional to it.

The use of passive cooling systems, in particular those for natural ventilation, has always been widespread in Mediterranean Countries, to cope with the difficult summer climatic conditions. In order to obtain the thermal energy necessary for heating and cooling indoor environments, passive systems work by exploiting only the natural phenomena of radiation, conduction, convection and ventilation.

There are numerous passive systems that can be adopted in a building, which necessarily vary in relation to the climatic and environmental context in which it is located, depending on maximization of solar gains (colder climatic contexts) or minimization of them (warm climates). An emblematic example of this is precisely the *Zisa* palace in Palermo: the building - expertly crafted - was characterized by the coexistence of an evaporative cooling system and natural ventilation, which, since its construction, has allowed the achievement of levels of environmental comfort that would still be satisfactory [2].

The project methodology of this study moves, first of all, from the in-depth analysis of the typological and material construction characters of the original studied building, promoting a rehabilitation that can architecturally redevelop it, improve the original technological level and energy efficiency, adding the necessary integrated services according to the intended functions, this design concept was effected using the planning participation in the choice of the new use of stakeholders (owners and for the urban decision also other stakeholders such as municipalities, tutelage Institutions).

The *Volta* electrical Power Station, located inside the harbour area (interested by the rehabilitation of the Palermo's waterfront), and near the ancient fortified castle near the sea (*Castello a mare*), as well as all power stations built at the end of the 19th century, really representing an example of industrial archaeology awaiting a recovery, using a private investment for its possible conversion to complementary and synergistic usages at the service of the same harbour area, as we can see in the 'figures 1-2'.

The building qualify itself as significant illustration of rehabilitation intervention, capable to respect memory but also to propose an improvement of energy performance, through a compatible and technological implementation, an upgrading of healthiness and quality of confined environments through high-tech integrated services and engineering choices. Before the bombings of the Second World War occurred in Palermo during the year 1943, the plant in its original configuration consisted

of an office and residential buildings (not however subject of this study), the boiler room, the distillers and pumps room, the engine room and the general switchboard and accumulators room [3].



Figure 1. Historic and general external view of the *Volta* Power Station in a photo of 1903 (private Collection).



Figure 2. External view of the *Volta* Power Station in a photo of 1930 (Dante Cappellani Archive)

The analyzed parts of power station insists on a lot of land, vast about 3200 square meters of soil, of which only the original engine room - built using a load-bearing masonry structure and covered by a double steel pitch roof with the introduction of top-ridge “lantern” openings - occupies an area large about 945 square meters; the no longer existing boiler room (having a plane extension of about 880 square meters) had an adjoining large and high chimney that no longer exists, and also the appurtenant garden can boast an extension of about 1300 square meters. The loss of its original function and - as often happens referring to all the similar examples of industrial archeology - was followed by the distortion of architectural forms: the boiler room in its exterior volumes was no longer rebuilt and the ground floor was refilled, the external area is devoid of appropriate functions, the engine room is in a state of neglect and poor maintenance, looking at ‘figures 3-4’.

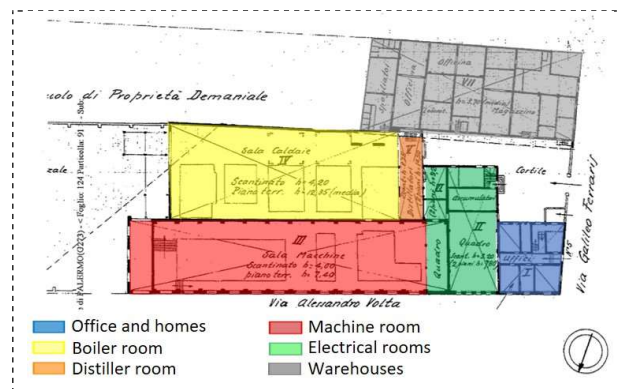


Figure 3. Cadastral map of 1940, with the indication of the different and original functions.



Figure 4. Aerial view of the actual state of the *Volta* power station.

Principal focus of the rehabilitation design of the new volumes is to preserve and restore all the original features of the existing site, including the external envelope (limestone masonry walls having a thickness of 60 cm) of the building and the big and steel reticular trusses of the roof as we can see in the ‘figure 5’. In an hypothesis of compatible rehabilitation and retrofit intervention, the new use purposed by the authors for the building is that to support and complete the activities pertinent the recovery of the harbor area and waterfront of Palermo in which it is inserted, with the function of a retail food market and the possibility of buyers to consume on site the products purchased and stop also enjoying the garden redesigned and systemized with all the other parts of the same harbor area: the boiler room will be rebuilt and put in communication with the engine room, the attic of the latter restored ground floor and reconfigured to adapt it to a technologically more efficient configuration of the roofing system.

The study carried out concerned only the engine room, with a particular attention to the technological/construction potential of the existing roof, improving the indoor comfort [4] [5]. Considering the good general conditions of conservation of the building, the intervention is simply characterized by the insertion of a passive evaporative cooling system that does not modify the original material-construction configuration. The building was characterized by a system of openings (at ground floor and at the top-ridge roof) that allowed the activation of a natural internal ventilation system which, before the numerous transformations, was able to guarantee a constant circulation of fresh air and expulsion of the hot one, as the ‘figures 5-6’ can illustrate.

With this study we want to demonstrate the importance of applying passive strategies for energy saving, in order to integrate them with the current conditions of traditional buildings, without distorting their original characteristics. This type of building is usually very energy-intensive because of a very high continuous internal comfort must be maintained during the use-hours

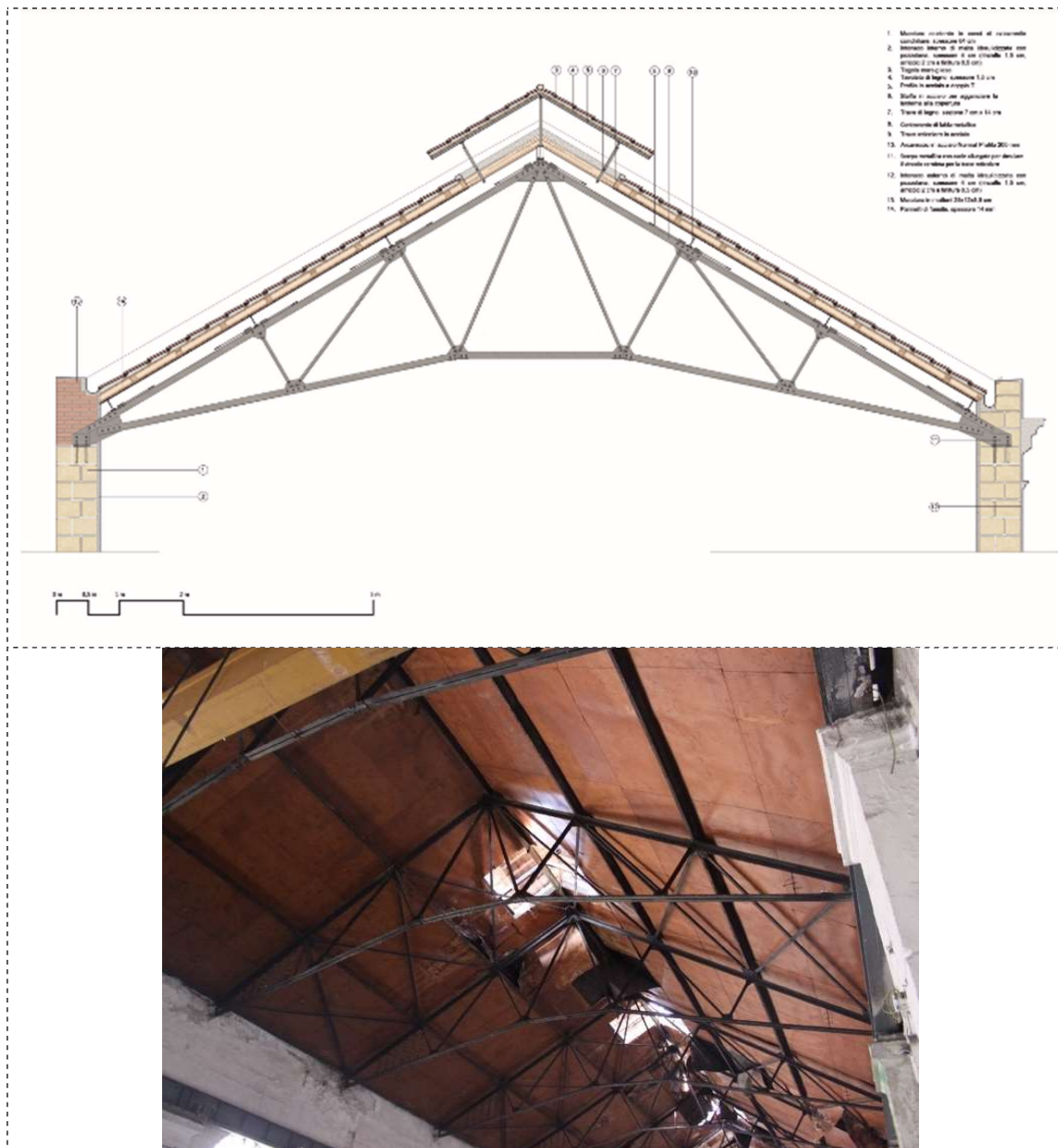


Figure 5. Construction section and interior photo of the *Volta* power station steel roof, with the top openings system (lanterns), useful to let out the hot air and also originally the smoke of machine.

2. Study Methods

The computer simulation for the study of natural conditioning, related to the *Volta* power station reconstructed boiler room, was carried out using an application methodology that uses various open source software available in the *CAElinux 2013, Linux* distribution.

The process phases for *CFD (Computational Fluid Dynamics)* analysis of the phenomenon were the following ones: a) definition of a volume geometry (solid modeling); b) generation of the calculation grid, discretizing the volume occupied by the fluid (meshing); c) numerical resolution of the equations that define the physical model and the boundary conditions up to the desired degree of accuracy (solving); d) display of the obtained results (post processing).

The volume of the building was designed so that it can be integrated with external modules for numerical calculation. Starting from the *CAD* drawings of the plans and sections of the project, the geometry of the engine room volume was designed using the different primitive entities, then the "faces" that delimit the volume were selected in order to proceed with the definition of the conditions contour and to the generation of calculation grids (mesh).

Then the scale of temperature, the thermic and physical characteristics of the fluid ("fluid properties") and the action of gravity ("gravity"), the initial temperature and velocity of the fluid volume ("volume conditions ") and boundary conditions ("boundary conditions") were selected. In the next section, called "calculation control" we have created any calculation points ("probes") that could record the value of the selected variable at each predefined time interval. Finally, the "calculation management" section allows us to start the calculation, able to generate curves showing the trend over time of temperature, of speed or other variables of interest, which also allows to view data in 2D and 3D.

It is thus possible to view the trend of each variable of interest in the plane or space dimension, as well as to create animations that show the trend of the air flow velocities within the volume.

This system of representing the temperature and air velocity trends made it possible to verify the operation of the retrofit system conceived in the energy rehabilitation design phase, in order to modify those elements that did not meet the requirements for the indoor comfort of the engine room. In particular, the steel roof has a linear thermal transmittance coefficient U equal to $1,4 \text{ W/m}^2\text{K}$, while that of the vertical walls is equal to $0,8 \text{ W/m}^2\text{K}$.

These data were included in the *Open Studio* program, calculating the actual internal climatic conditions. The proposal of an evaporative cooling system integrated with the roof "lantern" top-openings allows, in the summer period, the introduction of air at a lower temperature but, at the same time, with a greater amount of humidity.

The considerable height of the building allows the diffusion of a uniform nebulization that is not annoying in the lower part of the same building. In particular, two circuits of atomized water for the top "lantern" openings, serve the cooling coils installed in the central part of the steel roof. When the warm air rises upwards, it is cooled by the atomized water particles and is introduced into a cold air current which, having a greater density, descends downwards.

A passive evaporative cooling system (*PDEC*), like this one, using hydraulic nozzles allows a movement of descending air, so that the fresh air mechanically introduced descends downwards, avoiding the need for fans, ducts and false ceilings [6]. If the outside temperature drops below 28°C , only convective cooling is activated between the air openings located at the top and at the base of the building, in order to facilitate the entry of cooler air coming from below and its expulsion instead upwards: the air enters through openings located at the base of the ground floor and rises upwards due to "chimney effect", and then exits through the central "lantern" openings placed at the top of the building.

Using these passive strategies, the central area of the building not require the use of conventional air conditioning systems, significantly reducing energy and maintenance costs [7].

These technical solutions made the interior spaces comfortable, allowing them to be used even during the hottest periods of the year. Regards the heating during winter, fan coils powered by heat pumps were used. The maximum water temperature in the pump is 50°C . According to the simulations, the maximum demand is around 25-30 kW to heat the central space, bringing it from an ambient temperature of 8°C - 10°C during the winter period at the standard temperature of 21°C . Finally, the thermal inertia of the masonry helps stabilize conditions inside the building.

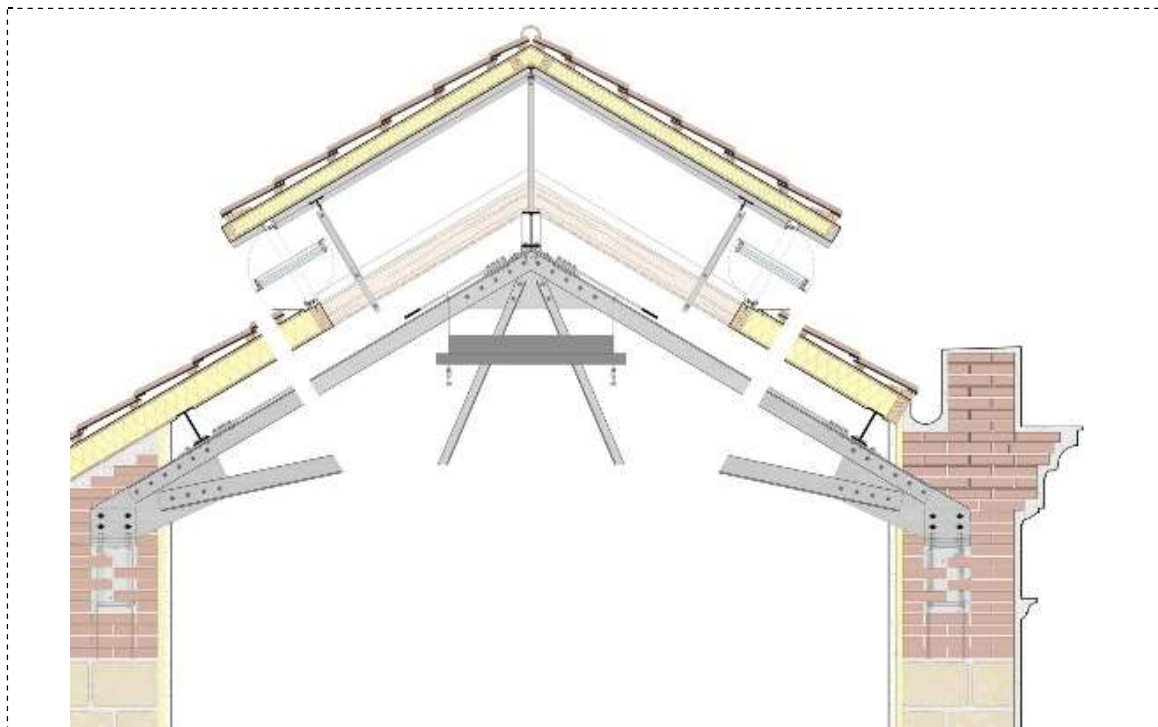


Figure 6. Retrofit design and construction section of the *Volta* power station steel roof, with the evaporative cooling system at the top openings (lanterns).

3. Result and discussion- Evaluation of the results achieved in hot humid climates

To passively contribute to the conditioning of the engine room, especially during the long and hot summer months, an evaporative natural cooling system has been set up, which can contribute to the mitigation of the internal temperature for most part of the year.

The same system was used in the Malta Stock Exchange building in Valletta, where the associate architectural studio Brian Ford & Associates has designed, referring on similar climatic conditions of Palermo, a mixed down-flow adiabatic cooling system to maintain the well-being indoor building conditions by minimizing the contribution of conventional systems [4].

The functioning verification of the adiabatic system designed for the machine room of the *Volta* power station in Palermo has been developed through simulations performed with thermal simulation software (such as *OpenStudio*, *Energyplus*, *Termolog*) of the solar path such as *Shadow Analysis* and of fluid dynamics such as *Fluent* it was possible to identify the most effective project strategies by verifying the results in terms of obtainable energy savings.

We have done some simulations effected using the *CFD* analysis, considering the most unfavorable climatic conditions both in winter (21th of December) and in summer (21th of June), also bearing in mind the hottest day (31th of July) and particularly at the hottest hour (at 3,00 p.m.), but in this study we would only better illustrate the simulation ascribing to the 21th of June, being it the most unfavorable.

A first *CFD* simulation has concerned the current conditions of the 21th of June, with an internal temperature of 33°C, detection of the air flow only entering from the window (0.2 m/s) and of the temperature of the same external air (32°C), as it can be seen looking at the ‘figures 7-8’.

Verifying a state of discomfort, another one *CFD* simulation method was required, effected again at the same date of 21th of June, applying the passive evaporative cooling system: the simulation graphs of the speed and temperature of the air allowed to verify the trend and distribution of the air flows and also returned information on the intensity of the flow so that this did not cause discomfort as can be evaluated by the ‘figures 9-10’.

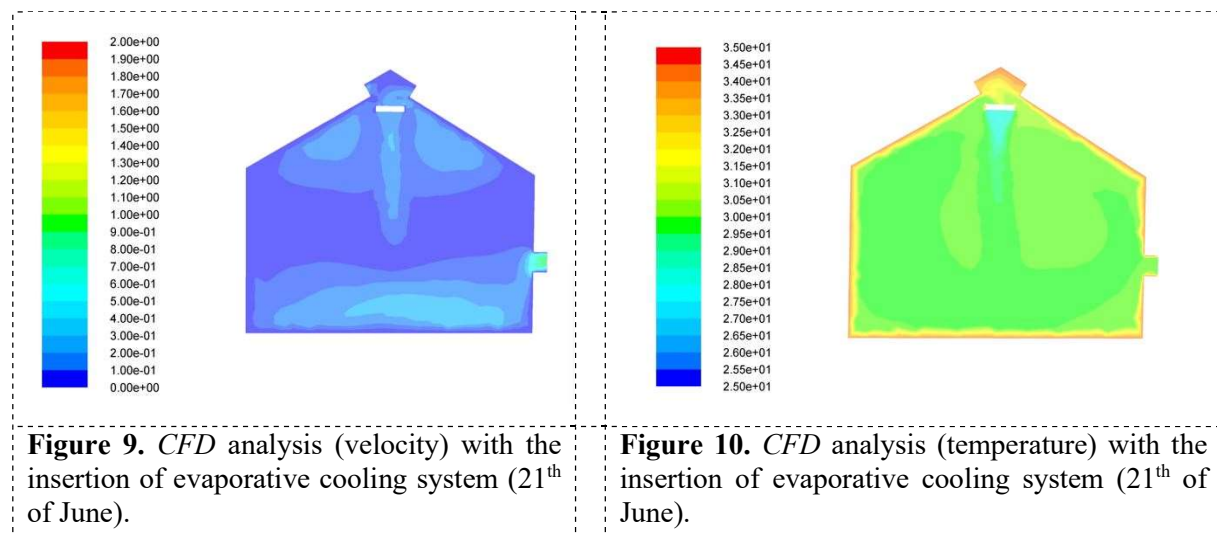
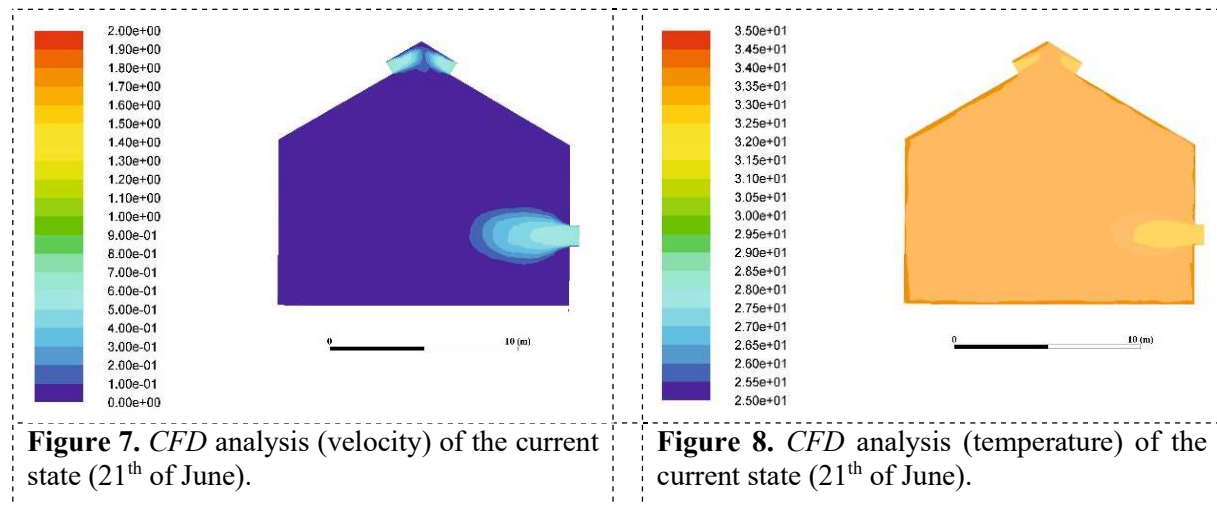
As it can be seen in the same ‘figures 8-9’, the presence of the nebulizers introduced in the retrofit project and positioned in correspondence of the top roof “lanterns” allow to the outdoor air, entering

from the lanterns, to cool down and increase its density, triggering a flow of descending fresh air that arrives at the floor of the machine room (see the “study methods” section).

The hot air, always at a temperature of 32°C, is humidified and cooled to 27°C and, mixing with the air inside the engine room, it reaches a temperature of 29°C, with a decrease of 3°C; this obtained data can be considered an acceptable level of internal comfort, according to the principles of adaptive thermal comfort [8] [9] [10] [11].

However, it will have to be specified that, currently, the integration of passive systems for air conditioning of public buildings is managed with difficulty, since it is not possible to completely eliminate the presence of conventional mechanical systems.

The *CFD* simulations and the possibility of use automation disposal for this hybridization [12] could provide new horizons and scenarios to be applied for a real reduction in energy consumption [12].



4. Conclusion – Possible and positive repercussions for Mediterranean architecture

The proposed approach provides criteria and methods of intervention, that can also be applied to other contexts, allowing to give a new life to abandoned and uninteresting buildings inside the historic city, triggering a fertile interest in the reconversion and activation of good practices, sensitizing the community through participatory design choices (as our design concept, effected using the planning participation in the choice of the new use of stakeholders as the same owner of the *Volta* power station and for the urban decision also the Palermo’s municipality and the Superintendence), that can introduce

good behaviours and opportunities capable of integrating functions, technological solutions, improving the quality of the built environment (human health) in a compatible way [12].

The contemporary rehabilitation and retrofit project - with its typological-functional, material-constructive, structural and environmental declinations - thus allows to return some forgotten urban places with strong primitive connotations to the new generations of designers and users, representative of the collective memory of a community that he had strongly desired and promoted, passing on the constructive culture and local identity.

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