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Integrated approaches for architectural decay mapping: a case study of the historic Tuna Factory "Florio" on Favignana Island, Sicily, Italy (IDEHA Project)

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Abstract – **This paper presents a multi-analytic study conducted as part of the IDHEA project at the former Tuna Factory "Florio," an architectural complex situated on the captivating island of Favignana within the Egadi Islands, Trapani, Sicily, Italy. As a 19th-century industrial archaeology pole, this site stands as an intriguing nexus of architecture, museum exhibits, and cultural significance, rendering it an ideal experimental ground for pioneering methods and technologies aimed at preserving, managing, and enhancing cultural heritage. Given its coastal location, the structures are highly susceptible to marine, geomorphological, and environmental threats, intensifying material degradation risks. In this study, different approaches were adopted for the inspection, decay assessment and architectural survey of the building complex, including 3D architectural surveys via terrestrial laser scanning, drone-based RGB photogrammetry, multispectral data collection, and direct inspections. This integration yields comprehensive data and intricate 3D models, aiding in pinpointing specific vulnerabilities. The study culminates in the implementation of a GIS platform that harmonizes all data, serving as a pivotal resource for managing and preserving this historically significant site.**

I. INTRODUCTION

The Former “Florio” Tuna Factory of Favignana is a historic industrial complex built in the second half of the 19th century inside the port of Favignana (**Fig. 1**), the largest of the Egadi Islands, Trapani, off the west coast of Sicily, Italy. Built by the prosperous Florio family, who were prominent entrepreneurs in Marsala, the Favignana tuna fishery operated for over a century until its closure in 1977. During its heyday, the tuna factory stood as one of the Mediterranean's largest and most productive tuna fisheries for the processing and conservation of tuna, covering over 7 hectares right on the coastline.

The first installation, called "Torino", was built in 1862 and underwent an expansion and monumentalization process between 1881 and 1886, probably by the architect F. La Porta, under commission of Ignazio Florio. In 1936 the ownership of the establishment passed to the Parodi family who continued the industrial activity until the 70s of the twentieth century. At its peak, in the early 20th century, the Florio tuna business employed over 3000 workers and processed tons of tuna yearly for export across Europe.

The complex was organized to fulfill any hunting and production stage, from tuna fishing to slaughtering, from cooking to canning, according to an industrial production model, with the use of a vast specialized local workforce.

The hub also included some boathouses for fishermen, factories for repairing the machines and a kindergarten for the children of the workers.

After a long period of abandonment and decay, between 2006 and 2008, the complex was finally acquired by the Sicilian Region. Subsequently, a comprehensive restoration effort was undertaken. This included the establishment of a museum that featured an expansive exhibition depicting the factory's everyday operations and the intricate world of tuna fishing. The museum also incorporated multimedia installations and showcased a collection of underwater archaeological artifacts, encompassing discoveries from the historic Battle of the Egadi Islands (241 BC) and other significant findings unearthed throughout the Archipelago.

Today, the Tonnara Florio holds a significant place in the cultural and historical tapestry of Favignana and the whole Sicily, as it stands as a testament to both the industrial prowess of the era and the deep connection between the island's economy and the sea. Around its impressive architectural elements, revolved a large part of the life of the local community and for this reason it is full of profound identity values.

II. "IDEHA PROJECT" FOR FAVIGNANA: OBJECTIVES AND METHODS

The coastal setting renders the architectural heritage uniquely vulnerable to a spectrum of marine, geomorphological, and environmental risks. These elements have the potential to serve as catalysts, hastening the deterioration of both the architectural structure and the materials housed within the museum (**Fig. 2**). Recognizing these challenges, the Tonnara of Favignana emerged as a strategic choice for conducting scientific endeavors within the framework of the "IDEHA Project – Innovations for data processing in the cultural heritage sector" [1]. This selection stemmed from its suitability as an ideal testing ground for assessing methods and technologies aimed at the preservation of architectural heritage.

Fig. 1. General view of the former Tuna Factory "Florio" in Favignana | © D. Pavone, CNR ISPC.

Fig. 2. Stabilimento Florio in Favignana (TP). Deterioration with alveolation and patina of the external wall surface | © G. Cacciaguerra, CNR ISPC.

The central goal of the IDEHA Project is to implement an open-source IT platform with the capacity to seamlessly aggregate diverse kind of content pertaining to cultural heritage. This platform aims to furnish comprehensive systems that ensure the sustainable management, protection, restoration, and preservation of cultural heritage undertakings. Furthermore, it seeks to seamlessly weave the cultural experience by integrating front-end applications and services, thereby enhancing the accessibility and enjoyment of cultural offerings.

In order to mapping the architectural decay, the IDEHA Project has experimented the following activities and technologies on the Former Tuna Factory "Florio":

1. An as-built 3D survey, using a terrestrial laser scanning and digital photogrammetry of the entire complex;
2. A general photogrammetry of the architectural complex realized through a drone survey in order to obtain an accurate representation of the building;
3. A multispectral map of some sectors of the building made with a drone in order to obtain a representation of the architectural decay and to identify partially visible structures;
4. A GIS platform for the management and spatial representation of all elements related to the state of conservation through the integration of 3D survey, photogrammetry and multispectral maps.

In this paper, our primary emphasis will be placed on the construction of the 3D model and its integration with RGB drone photogrammetry, multispectral mapping, and direct visual inspection. This comprehensive approach allows us to meticulously assess distinct aspects and intricacies, forming a cohesive foundation for our GIS platform. By seamlessly integrating this array of information, we not only fortify our understanding but also create a thorough data resource that proves instrumental for the efficient management and preservation of the buildings.

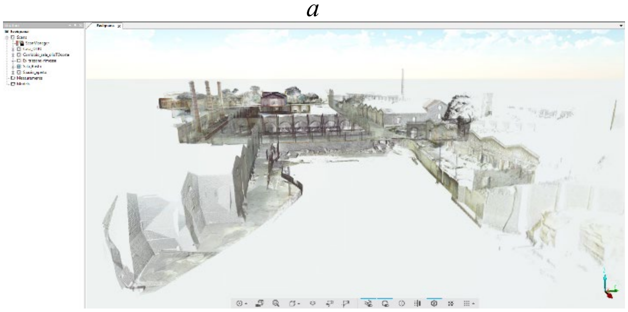
III. 3D LASER SCANNER SURVEY

The 3D survey of the architectural heritage was conducted using the Faro Focus 3D S120 terrestrial laser scanner (TLS). This device operates on phase-shift technology and has been previously validated [2]. It automatically captures 3D spatial coordinates (976,000 points per second) of a scene, resulting in a densely populated cloud of data that is both photorealistic and metrically accurate. The device has a 360° field of view on the horizontal axis and 305° on the vertical axis. Its operational range spans from 0.6 meters to 120 meters, exhibiting a linear distance error of ±2 mm between 10 meters and 25 meters. Additionally, the instrument incorporates a 70-megapixel coaxial camera that captures data within the same reference system as the point clouds. It simultaneously associates RGB color values with each recorded point.
Beyond the outdoor environments, the survey was extended to encompass several indoor spaces (**Fig. 3**) including the former carpentry shop, now transformed into a museum which exhibits some of the roman *rostra* from the Battle of the Egadi, the old “Trizzana”, which houses a boat wreckage and the so-called "Casa dell'olio", an exhibition space for the tuna processing products.
The acquisitions, including 109 scan locations, were processed using the software “Faro Scene”. The workflow included: automatic filtering for the elimination of points with reflectance lower than a certain preset value that could interfere with the readability and reliability of the obtained geometries; coloring; manual alignment; automatic location cloud to cloud.

Fig. 3. The TLS survey of some indoor environments of the complex: acquisition and modeling |© D. Giuffrida and R. C. Ponterio, CNR IPCF

The resulting 3D model boasts a high level of metric accuracy, ensuring precision in its representation. Utilizing this model, users are afforded the ability to navigate through a photo-realistic point cloud and generate diverse perspectives, including sections, floor plans, and other visualizations (refer to **Figs. 4** and **5**). This model has been seamlessly incorporated into a Geographic Information System (GIS), allowing for the combination of outcomes from various resources, such as multispectral data and direct verification data. This integration empowers us to comprehensively assess structural concerns, decay phenomena, and undertake comprehensive risk assessments.

a



b

Fig. 4. Different views of the final dense cloud, from the Faro Scene software: a. point cloud of some rooms; b. prospective clear view of the Plaia Bay |© D. Giuffrida and R. C. Ponterio - CNR IPCF

Fig. 5. N-S section of the complex. |© D. Giuffrida and R. C. Ponterio, CNR IPCF

IV. DRONE SURVEY AND PHOTOGRAMMETRY

The survey activities were supplemented by comprehensive photogrammetric analysis of the historic factory. The acquisitions were carried out with a DJI Mavic 2 Pro equipped with a Hasselblad camera (1" CMOS, 20mpx sensor) with a focal length of 28 mm at f/2.8 aperture. An ND (Neutral Density) filter was also added to the camera. The two nadiral flights were planned and programmed through the use of an automatic remote pilot system (DJI Ground Station Pro) at an altitude of 30m. The images were acquired with an overlap and sidelap modulus of 60% and a ground resolution of 0.7 cm/px. Georeferencing was achieved with the realization of a polygonal acquired with a Trimble R2 GNSS Station - TSC3.

The result was optimal and made it possible to obtain an accurate photogrammetry of the structure and to observe unknown areas of the ancient building and to verify its state of conservation (**Fig. 6)**. In particular, it was possible to identify the horizontal axis of inclination of the three eastern smokestacks, which have an evident structural problem and on which conservation work would be necessary.

Fig. 6. General Photogrammetry of the architectural complex. | © G. Cacciaguerra and S. Barone, CNR ISPC

V. Multispectral Survey: The Plaia Bay

Utilizing multispectral drone technology, we conducted a comprehensive inspection aimed at identifying partially concealed architectural structures and discerning potential indicators of decay caused by marine environment, biological and microchemical agents [3, 4, 5].

The multispectral survey was targeted at a specific area of the old architectural complex: the so-called 'Plaia', a small bay located north of the Factory.

The acquisitions were made with a DJI Phantom 4 Multispectral, an instrument mainly used for expeditious acquisitions in the field of agronomy and still little used in cultural heritage research [6]. The drone is equipped with six 2.12 mpx cameras with a focal length of 5.74 mm and a fixed f/2.2 aperture, which allow RGB and single-band Blue (B, 450 ± 16 nm), Green (G, 560 ± 16 nm), Red (R, 650 ± 16 nm), Red-Edge (RE, 730 ± 16 nm) and Near-InfraRed (NIR, 840 ± 26 nm) images to be acquired.

The acquisition system of this drone allows for each individual flight the recording of one image for each of the different bands (B, G, R, RE, NIR) and one image for RGB or for only one of the NDVI (Normalized Difference Vegetation Index), GNDVI (Green Normalized Difference Vegetation Index) or NDRE (Normalized Difference Red Edge) vegetation indices. The presence of the solar irradiation sensor allows real time radiometric calibration in order to provide accuracy to the acquired multispectral data.

The flight was planned and programmed through the use of an automatic remote piloting system (DJI Ground Station Pro) at an altitude of 30m. The individual images were acquired with an overlap and sidelap modulus of 60% and a ground resolution of 2.1 cm/px. The flights were conducted in marine low-height wave conditions.

The processing of the maps derived from the multispectral acquisitions was carried out using Agisoft's Metashape software, which produced satisfactory results in the representation of the Vegetation Index. At this stage, in addition to the five different individual bands of the spectrum, only the NDVI index ((NIR-RED)/(NIR+RED)) was processed.

The general NDVI index map allows to identify two important aspects related to degradation and diagnostics. First, it was possible to identify the presence of micro seaweed on numerous sectors of the quay facing the coast and on the lower part of the walls of the "Malfaraggio" that cause slow processes of decay of the stone surfaces and, above all, of the mortars. Secondly, the multispectral survey made it possible to identify the structures related to an old landing place of the factory (Wall 2), broken into five segments (a-e), partially underwater through the different seaweed growth [7] (**Figs. 7 and 8**).

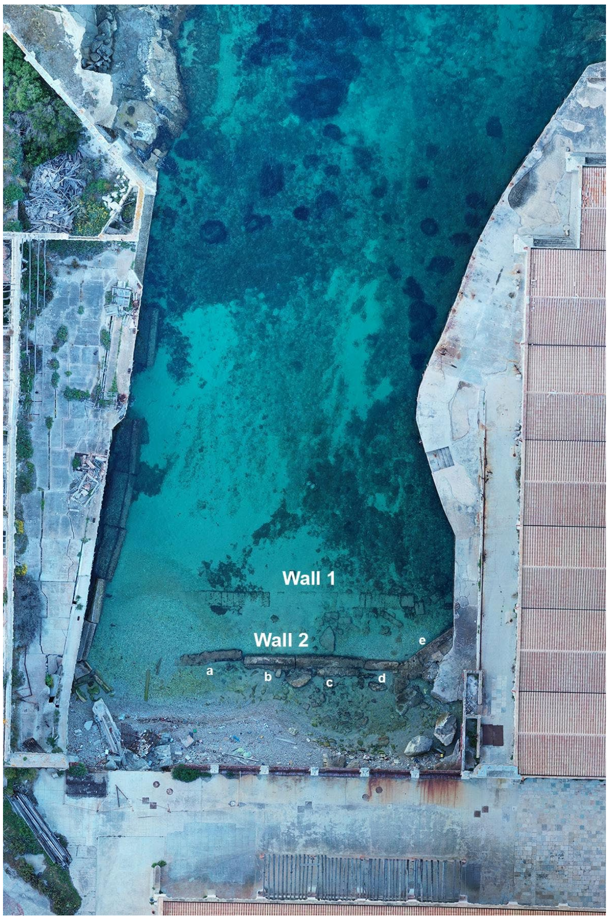


Fig. 7. Photogrammetry of the Plaia Bay: underwater structure (Walls 1-2). |© G. Cacciaguerra and S. Barone, CNR ISPC

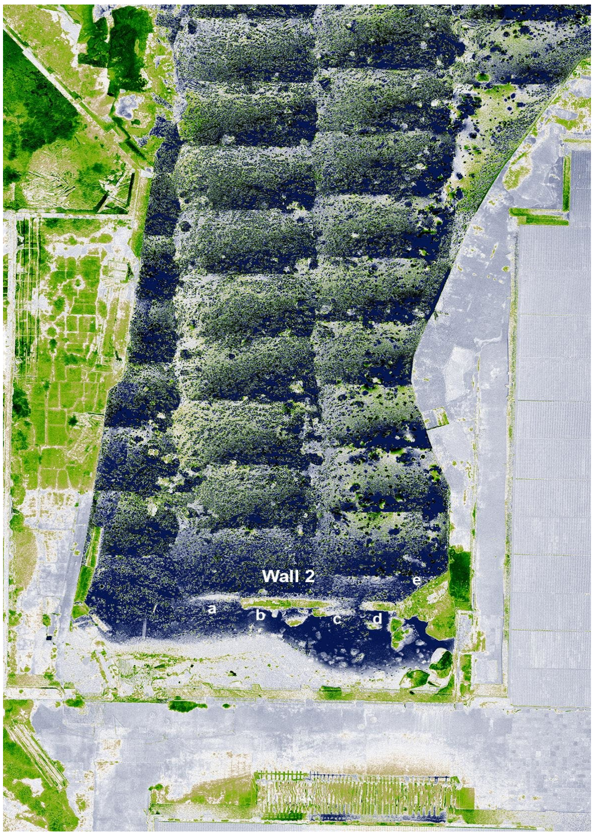


Fig. 8. NDVI Index Map from Multispectral Drone Survey: The Wall 2 identified through different growth of algae. |© G. Cacciaguerra and S. Barone - CNR ISPC.

VI. Conclusion

Thanks to the levels of detail achieved by the acquisitions as well as by the metric and multispectral data, the digital maps created will be able to contribute to the analysis of the architectural decay on a coastal monument. The combined study of 3D, photogrammetric and multispectral acquisitions provide an initial insight into specific aspects of the monument's architectural deterioration. The integrated photogrammetry and multispectral maps clearly indicate the role of algae and microalgae in degradation processes in particularly vulnerable areas of the historic building. The set of data collected through the architectural survey populated the GIS Platform and provided a general representation of the building's state of preservation.

Finally, the interventions carried out have also gained the interest by the Municipality of Favignana and local authorities, which, on the basis of the data acquired within the IDEHA project and in synergy with the subjects involved in the project, have shown interest in specific consolidation, restructuring and securing of some sectors of the complex that will affect future interventions.

VII. Acknowledgements

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