Port of Malfa **– renewal and extension of the port of Malfa, with definition of the existing external breakwater - project developed in an UNESCO WORLD HERITAGE SITE – pilot test of reforestation of Posidonia Oceanica as environmental compensation**

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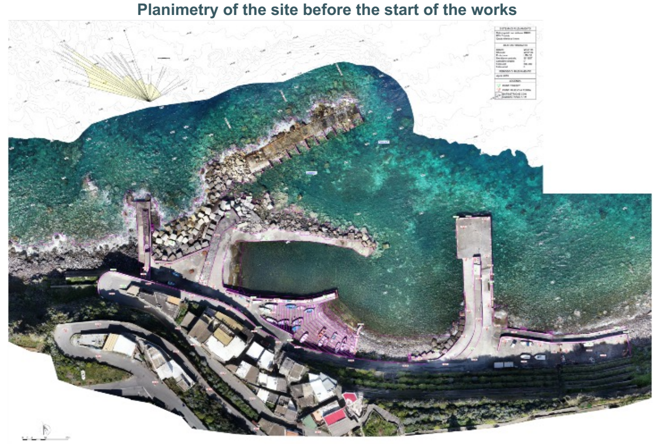
Assessorato delle Infrastrutture e della mobilità - Dipartimento delle Infrastrutture, della mobilità e dei trasporti
Servizio 6 – Infrastrutture marittime e portuali

Localization of the Project – Island of Salina – Eolian Archipelagos – Malfa

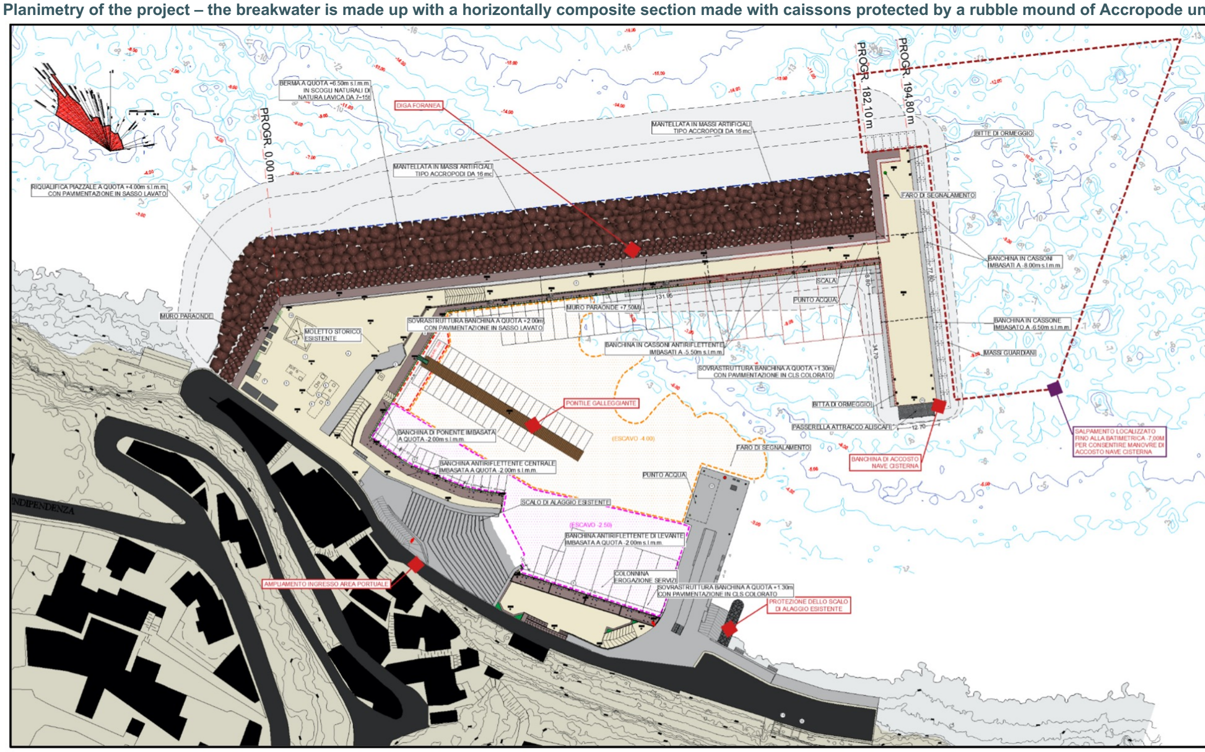
Port of Malfa

Planimetry of the site before the start of the works



Render of the Project

Planimetry of the project – the breakwater is made up with a horizontally composite section made with caissons protected by a rubble mound of Accropode units



BRIEF DECRIPTION OF THE SERVICE	Renewal and extension of the Port of Malfa –the entrance door the Vulcanic Island of Salina, characterized by a significant exposure to northwest swells, steep seabed and paramount environmental considerations, being a UNESCO WORLD HERITAGE SITE and natural site protected by the European Union (Natura 2000 network). Designed with meticulous engineering precision, this advanced port infrastructure integrates seamlessly with the natural surroundings while addressing the complex challenges posed by wave dynamics and environmental factors
LOCATION	Harbor of Malfa – Island of Salina
CLIENT	Municipality of Malfa & Regione Siciliana
TIME OF EXECUTION OF THE SERVICE	08/2021 to 10/2023
KIND OF SERVICE	Master Planning, Environmental Impact Assessment, Constructive Design, Construction Management, Safety supervision and coordination
TOTAL COST OF THE WORKS	**€ 20. 950.000 (20.95 millions)**

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Project n. 1

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Example of intense storm (Hs = 5.00 m) before the start of the works

Render of the Project

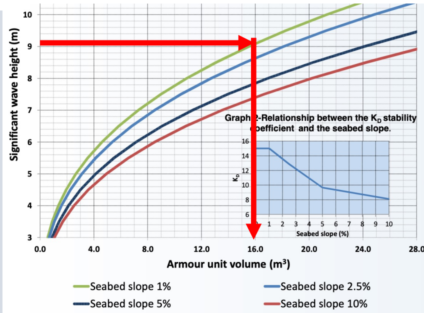
Render of the Project

The Scalo Galera breakwater, located north of the island of Salina in the Aeolian Islands archipelago, **is particularly exposed to swells coming from the N & NW direction ("Maestrale"). According to the Extreme Wave Climate analysis, the significant wave height, with a 100-year return period, was found to be Hs = 9.01 m, from the NW direction.**
The unique exposure and wave characteristics (one of the highest that is found in the Mediterranean Sea) means that the breakwater necessitate engineering choices that would enable it to withstand exceptionally intense waves while reducing costs and minimizing impact on the very valuable environment and marine ecosystem.

The chosen design approach involved the utilization of a Accropode I technology, employing units with a volume $16m^3$ in order to satisfy the stability analysis with the significant wave height considered, while reducing the totale amount of Concrete needed. This technology allows for cost reduction compared to other techniques involving double-layered concrete blocks, and also **minimizes the footprint of the offshore breakwater on the seabed, offering evident environmental advantages**. The offshore breakwater, considering the particularly substantial seabed slope due to the volcanic origin of the site, has been designed as a composite structure using cellular caissons protected by a rubble mound made of natural rock armor with 16 m^3 Accropode units. The cellular caissons will be filled with concrete on the seaward side to ensure greater resistance to wave impacts, while the landward side will be filled with rubble. The caissons will be equipped with a reinforced concrete superstructure, which will include the construction of a wave barrier wall up to an elevation of +7.50m above mean sea level.

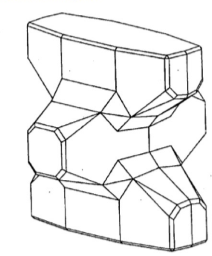
The closure of the offshore breakwater will be realized through the arrangement of adjacent cellular caissons, each with dimensions of 26 m x 13 m and varying height.
To enhance the functionality of the breakwater, the internal cells within the caissons will be filled with concrete.
One significant advantage of this construction approach lies in its ability to yield a spacious berthing platform along the breakwater. **This platform will serve as a docking area for tanker ships, facilitating the crucial supply of potable water to the island, and also, in case of the need of an emergency evacuation of the Malfa village, to berth a passenger vessel.**
With an elevation of +2.00m above mean sea level, the berthing platform ensures optimal accessibility and operational efficiency for the water tankers, allowing for seamless loading and unloading operations.
To further enhance safety and protect both the breakwater and the vessels, the berthing platform will be equipped with arch-type fenders. These specialized fenders act as a cushioning system, absorbing impact forces and minimizing potential damage during the docking process. Additionally, heavy duty bollards will be strategically placed along the platform, capable of withstanding significant pulling forces of up to 50 tons. Through the integration of these engineering elements, the completed berthing platform not only ensures the safe and efficient delivery of potable water but also establishes a resilient and functional maritime infrastructure that aligns seamlessly with the objectives of the project

Design of the Accropode Units



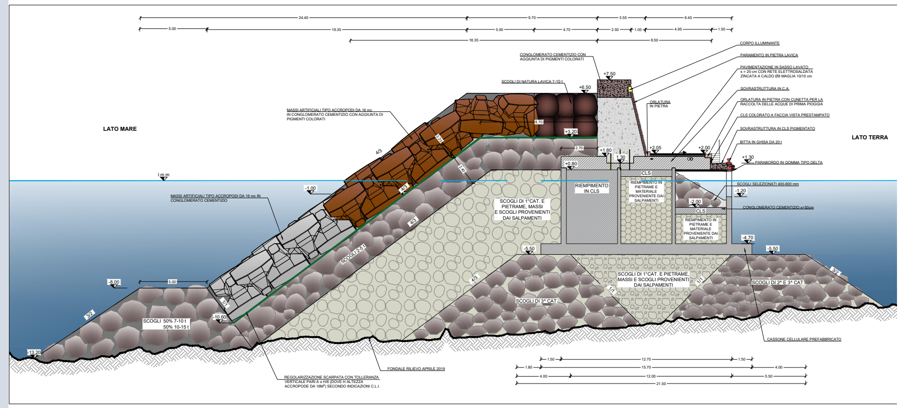
Volume V (m³)	V = 0.34 H³	1	2	3	4	5	6	8	10	12	[illegible]	16	[illegible]	20	22	24	28
block Height H (m)	H = (V/ 0.34)$^{1/3}$	1.43	1.81	2.07	2.27	2.45	2.60	2.87	3.09	3.28	[illegible]	3.61	[illegible]	3.89	4.01	4.13	4.35
Armour thickness T (m)	T = 0.9 H	1.29	1.63	1.86	2.05	2.21	2.34	2.58	2.78	2.95	[illegible]	3.25	[illegible]	3.50	3.61	3.72	3.92

Intermediate sizes are available on request.

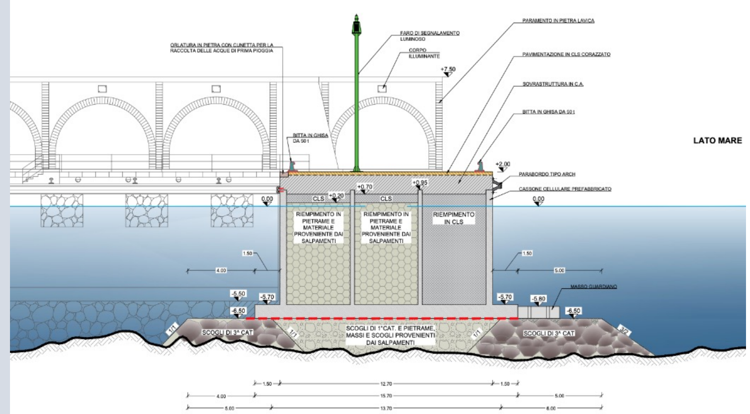


GENERAL SHAPE OF THE ACCROPODE™ BLOCK

Typical horizontally composite section of the project – the internal caisson (with the anti-reflective cell) work as a berth



Cross section on the head



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In small ports, the design of antireflective docks becomes crucial due in order to reduce the reflection of the waves that can penetrate inside the harbor , in order to reduce the internal agitation. When waves approach a dock, they exert a significant amount of energy onto the structure. If the dock is not designed to mitigate wave reflection (for example, if it is a completely vertical berth), the waves can bounce back off the dock's surface and create unwanted resonance wave patterns within the port, that will make the structure as an all unsafe also for moderate external wave climate.

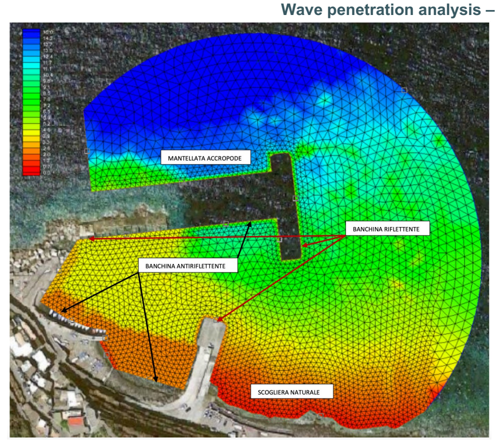
This wave reflection can lead to several issues. Firstly, it can cause increased turbulence and agitation within the port, making maneuvering vessels more challenging and potentially compromising the safety of navigation.

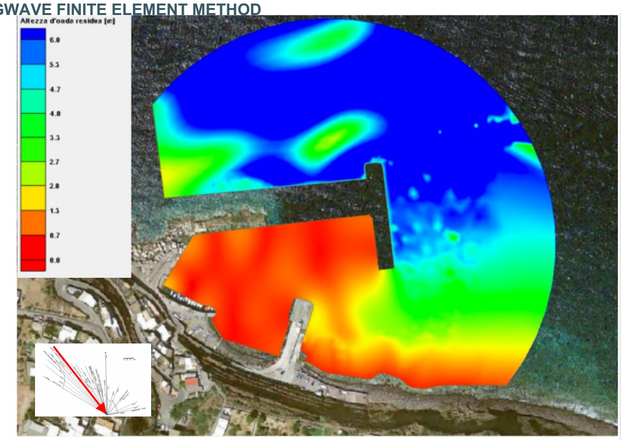
Additionally, the reflected waves can result in increased stress and pressure on the dock itself, potentially leading to structural damage over time.

By **incorporating antireflective design** features into the dock, such as energy-absorbing materials, or submerged structures**, the impact of wave reflection can be minimized**. These design elements help to dissipate the energy of incoming waves, reducing the reflection and preventing the creation of undesirable wave patterns within the port.

The implementation of antireflective docks in small ports is essential **to ensure smooth and safe operations**, mitigate structural stress, and maintain a calmer and more controlled environment for vessels and maritime activities. It is a vital consideration in the design and construction of small port infrastructure to optimize functionality, efficiency, and overall safety for the small vessels that will use the port.

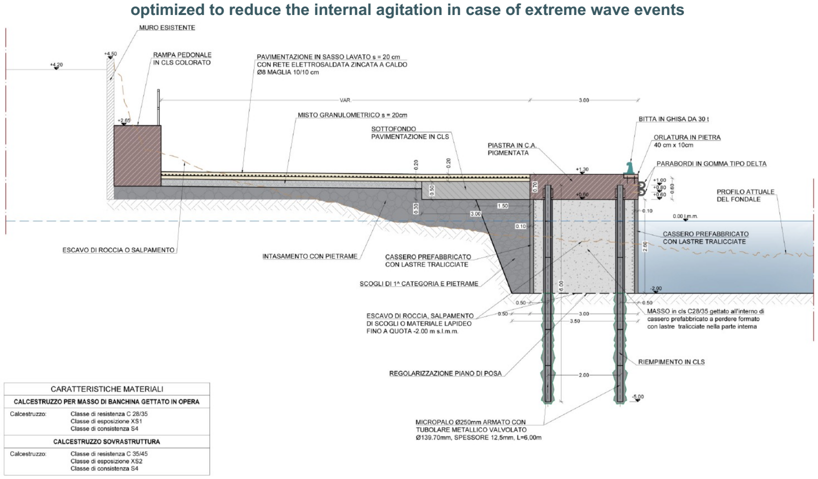
Wave penetration analysis – CGWAVE FINITE ELEMENT METHOD



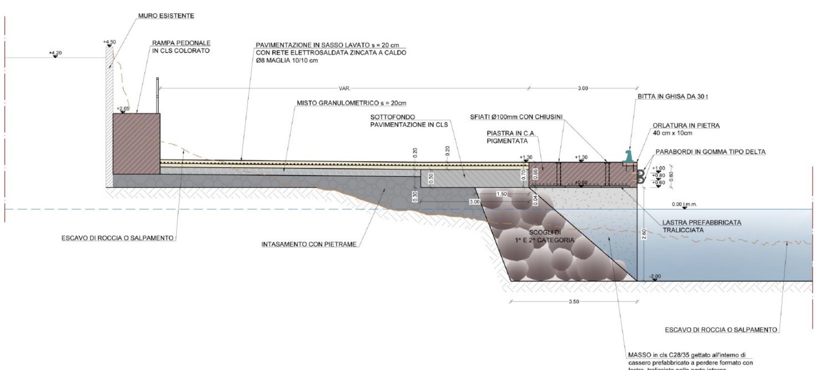


SEZIONE 1 - Scala 1:50

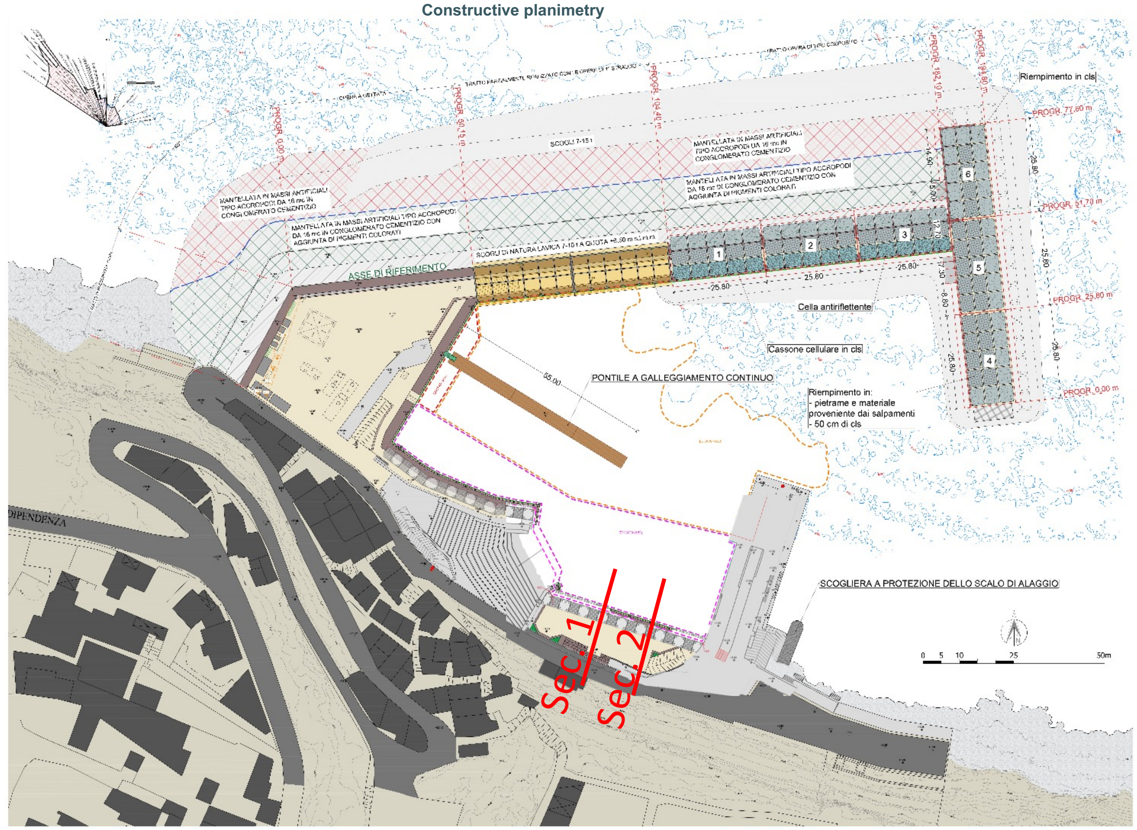
Two section of the new land-side berth, one with full vertical structure and one with and anti-reflection cell, optimized to reduce the internal agitation in case of extreme wave events



SEZIONE 2 - Scala 1:50



Constructive planimetry



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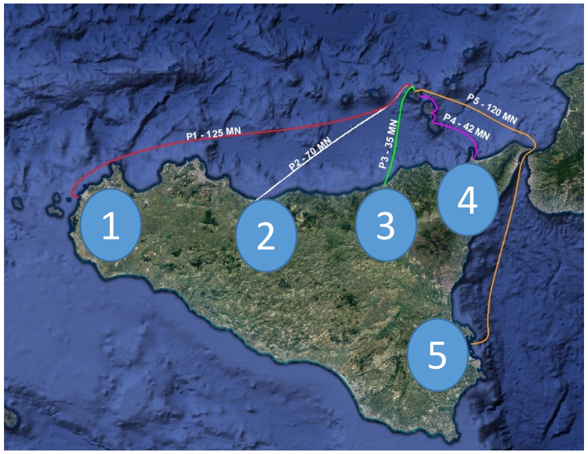


Construction site challenges

The construction began in 2021, and since then, significant progress has been made towards its completion. However, the project faced challenges in terms of sourcing construction materials on the island of Salina. Due to limited availability and difficulties in transportation, it became necessary to establish additional construction sites in Sicily. These satellite sites were established to handle the macro-scale processes required for the project and in particular:

1. Trapani: Rocks furniture
2. Termini Imerese (PA): Caissons realization
3. Sant'Agata di Militello (ME): Casting Accropode
4. Milazzo: RoRo transfers
5. Augusta (SR): volcanic rocks furniture

Despite the logistical obstacles, the team persevered and adapted their approach to ensure the project's successful execution. The multiple construction sites allowed for efficient distribution of resources and enabled the completion of various phases simultaneously. As the project approaches its final stages, the coordination among the different sites has been crucial in achieving the desired outcomes. The construction team's dedication and flexibility, combined with strategic planning, have ensured progress towards the project's ultimate goal – the successful completion of the undertaking

Installation of caissons

Another particularly delicate phase of the project involved the installation of cellular caissons 26,00mx15,00mx6,00m sourced from the Termini Imerese construction site..

The caissons were initially transported to Malfa using two tugboats. Subsequently, through selective filling of the internal cells, they were submerged onto the previously prepared foundation. This process was facilitated by three motorized pontoons responsible for transporting the material, positioning it, and bringing the caisson

SURVEYS

Survey of the INSPECTED WORKS built with ACCROPODE™ armour units has been done by photogrammetric technics for the above water level part by using a **drone** with RTK correction coupled with a LiDAR sensor, while **multi beam** bathymetric survey for the underwater part by using georeferenced echo sounder with a high performance multibeam sonar capable of resolution up 500 points/m2.

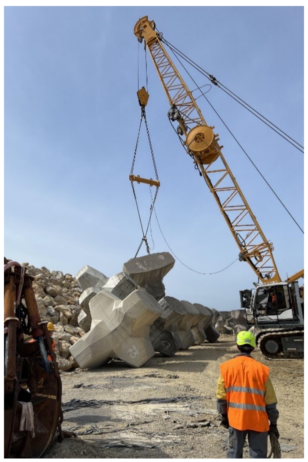
Accropode installation

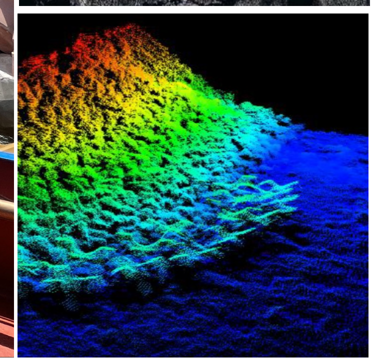
Due to the potential difficulties associated with the installation of 16m³ accropodes in a single layer, it was deemed necessary to conduct ground tests. These tests were essential in instructing crane operators on the precise positioning of the stones according to the project's designated laying plan. The objective was to ensure that the accropodes were installed correctly and securely to meet the structural requirements.

The chosen location for these crucial tests was the accropode construction site in Sant'Agata di Militello. Conducting the trials on land provided a controlled environment where crane operators could familiarize themselves with the handling and placement techniques. By **simulating the actual installation process, they could practice and refine their skills, minimizing the risk of errors and ensuring the efficiency and accuracy of the subsequent** marine installations.

The ground tests not only served as a training exercise but also highlighted any potential challenges or issues that could arise during the actual installation at sea. They allowed the team to identify and address any logistical or technical difficulties, ensuring a smoother and more successful execution of the project.

Through these meticulous preparations, the construction team aimed to mitigate risks, optimize operations, and enhance the overall quality of the accropod installation. **The knowledge and experience gained from the ground tests would be invaluable as the team ventured into the marine environment, ensuring that the installation process would be carried out with precision and adherence to the project specifications.**





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Reforestation of P. Oceanica

The project for the creation of the new breakwater in Malfa is inserted in highly valuable environment, that is protected by the European Union (Natura 2000 sites network).
In order to minimize impact on the seabed a replanting part of the Posidonia Oceanica was carried out.

The developed method useses an anchoring module for reforesting the seabed with marine phanerogams (like Posidonia Oceanica), made of plastic-free material.

The anchoring module facilitates the rapid and effective installation of P. oceanica reforestation by employing a low-impact environmental system. It ensures the secure and efficient fixation of plant organisms to the seabed, promoting their establishment, growth, and natural developmental dynamics, easing the development of new roots.
The developed device was patented with Italian Law.Key principles underlying the patent are as follows:

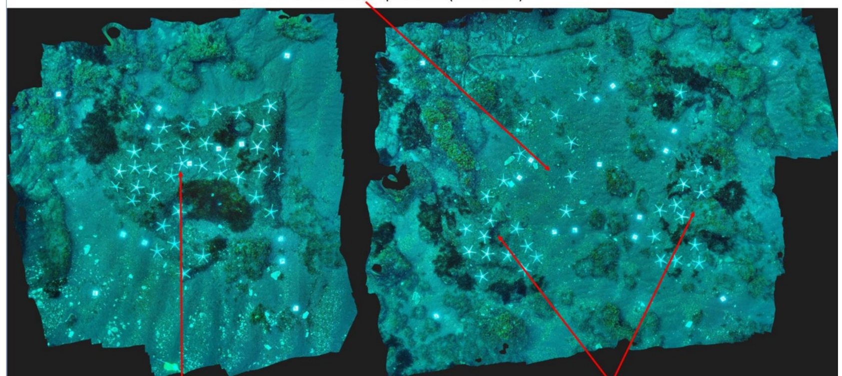
- Extensive utilization of biodegradable and compostable plastic materials to ensure the eventual dissolution of the support structure for the shoots upon root establishment.
- Modular system design, enabling high flexibility in seabed coverage strategies and adaptability to various plant species.
- Simplification of anchoring techniques to enhance efficiency in installation and reduce costs.
- Utilization of bioinspired geometries that emulate the natural colonization patterns of plants on the seabed.
- The anchoring module features a five-arm radial structure that can accommodate shoots/rhizomes, constructed entirely from naturally derived bioplastic material (Mater-Bi®). It is anchored to the seabed using a quick-fix stake

The radial structure is modular, with a central node that fits into the stake, and the arms are equipped with supports inclined at approximately 41° (Marbà and Duarte, 1998) to mimic the clonal expansion angle through which the plants naturally colonize the seabed. This system also allows for the secure attachment of P. oceanica seedlings using appropriately sized attachment supports.
The bioplastic material (Mater-Bi®) utilized in the anchoring module has demonstrated no toxic effects on marine organisms and exhibits biodegradation rates compatible with the rooting and stable fixation of shoots to the substrate at the planting site (Campani et al., 2020). The marine biodegradation results have also been verified by Certiquality within the Environmental Technology Verification (ETV) pilot program, which assesses the performance of innovative environmental technologies that may impact human health or the natural environment.
Specifically, the anchoring system enables the rapid positioning of P. oceanica plants on the seabed, promoting their attachment, growth, and facilitating the natural dynamics of prairie development.

Posedonia Oceanica reforestation intervention in Malfa – made (in two nearby area where the previously existing Posidonia Ocenanica matte were killed by the frequent anchoring of the water tanker vessel) were monitored producing submerged photogrammetry, as in the figure below

Approved by Ministry of Environment: Decreto di esclusione dalla procedura di VIA n.269 del 12.10.2022

Sub-area C – sabbia con pietrame (11 moduli)

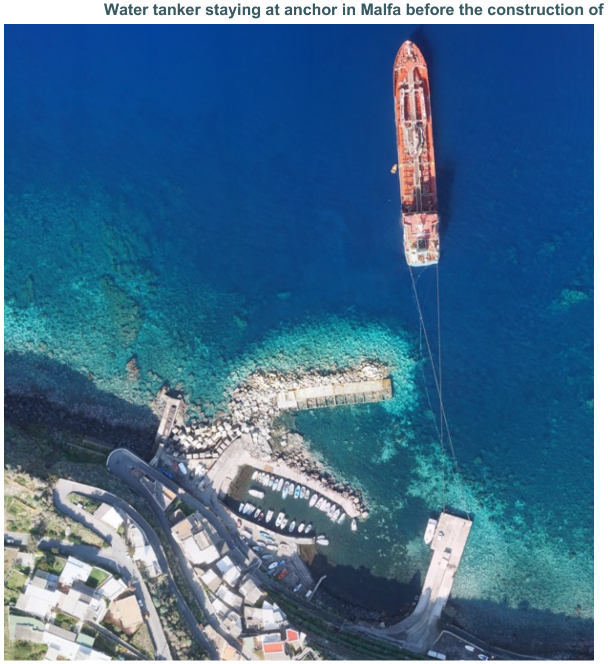


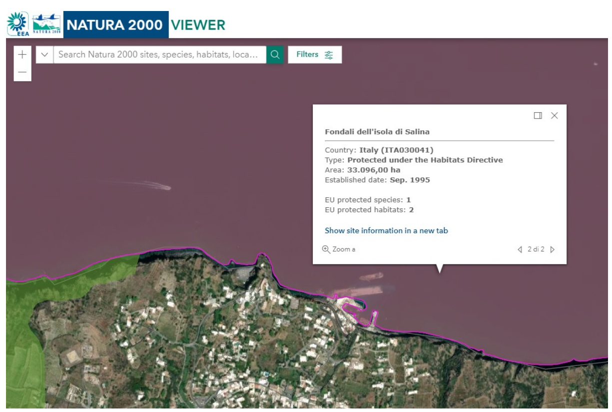
Sub-area A – *matte* morta (36 moduli)

Sub-area B – *matte* morta 23 moduli

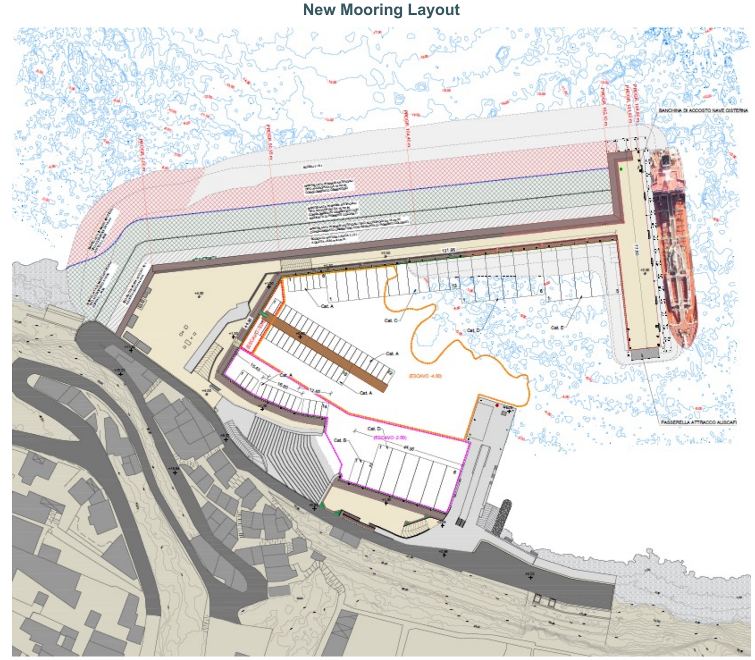
Reforestation intervention pictures

Water tanker staying at anchor in Malfa before the construction of the new breakwater





New Mooring Layout



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Importance of Civil Protection

In geographical contexts such as these, effective planning and prompt response to emergency situations can make the difference between life and death.
Small isolated islands, such as Salina, represent a natural beauty, but are also vulnerable to natural disasters and emergencies. These islands often have limited access to resources and infrastructure, making adequate preparation for emergency situations essential.
Moreover, the reasons set out above are all the more corroborated by the consideration that the island of Salina has no airport facilities, which is why the only access route for rescuers and escape route for the population is by sea. The risk situation is further aggravated by the absence of a Fire Brigade garrison, which could worsen further in the event of a fire. In fact, support from land is essential for rapid access to places on the island in order to severely limit damage to the natural and cultural heritage, especially in areas of environmental and landscape value such as the island of Salina

Civil Protection:
Civil protection is a crucial element in ensuring the safety and well-being of local communities. Through targeted planning and the implementation of preventive measures, civil protection can mitigate risks and minimise the effects of natural disasters, accidents or health emergencies.

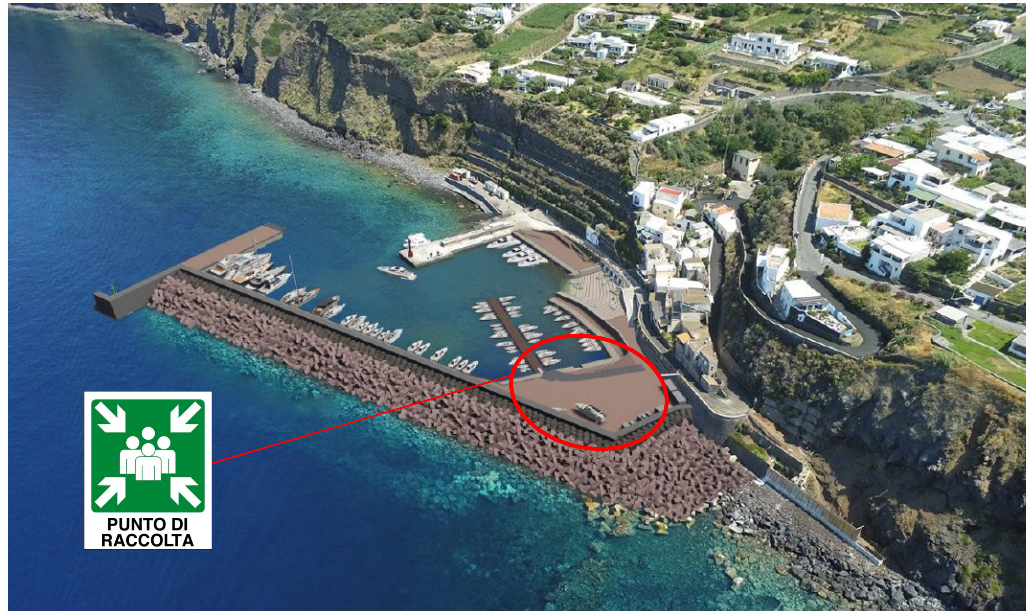
Escape routes:
Escape routes are predefined and safe routes that allow people to quickly move away from areas at risk in the event of an emergency. **On small isolated islands such as Salina, it is essential to identify, mark and maintain these escape routes in good condition to ensure rapid evacuation in case of need.**

Assembly points:
Gathering points are designated places where people can congregate after being evacuated from areas at risk. These assembly points should be strategically located to be easily accessible and provide immediate assistance, such as food, water, health services and psychological support.

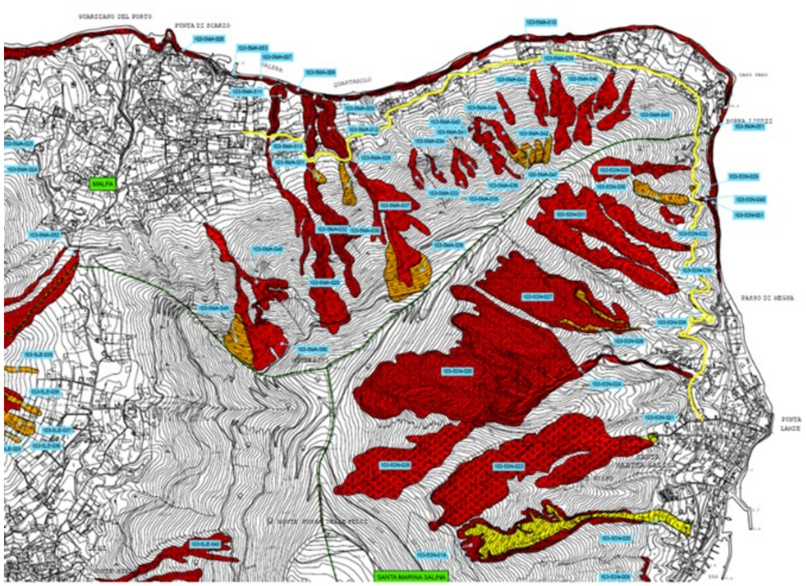
Examples of civil protection measures in Salina
Salina, like many other islands in the Aeolian Islands, has implemented specific civil protection measures to address the unique challenges of isolation. These measures include establishing an early warning system, training the population on evacuation procedures, setting up appropriate assembly points and working with the relevant authorities to ensure a coordinated and timely response to emergencies.

Flood effects in the Aeolian Islands in 2022

New emergency collection point for the population at the new port of Malfa



Track of the S.P. 182 (in yellow) in the section between the towns of Santa Marina Salina and Malfa. In red the active instabilities surveyed by the P.A.I.



Fire on the Eolian island of Stromboli on 25 and 26 May 2022