Jornadas de Obras de Interés Geotécnico.
59ª Sesión. DRACE GEOCISA/MENARD

GENOA new breakwater, Italy

Jérôme RACINAIS

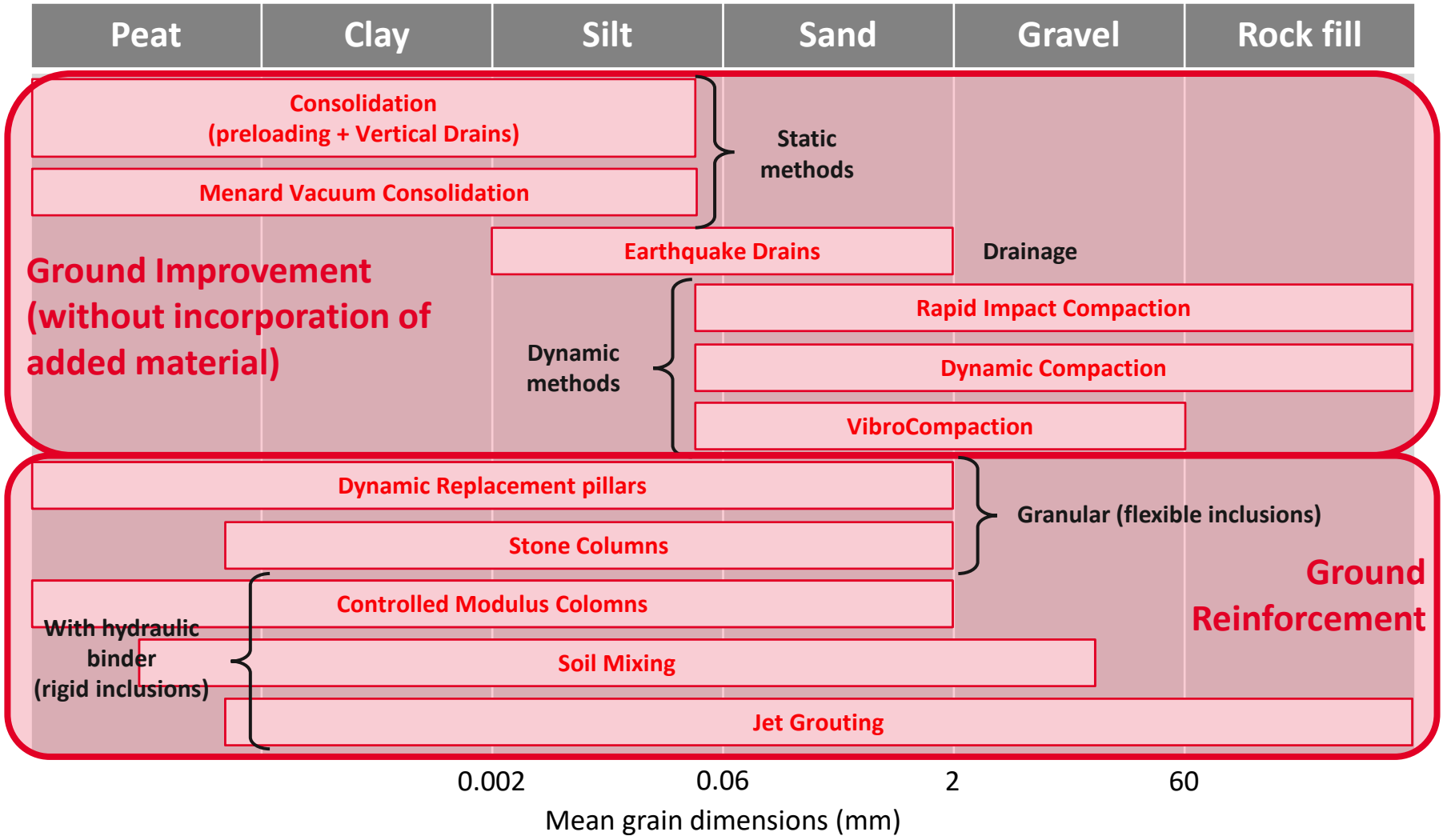
Engineering Director

menard

Summary

1. Stone Columns – Principles and Practice
   a. Ground improvement techniques
   b. Execution methods
   c. Scope of application
   d. Structures and objectives
2. New breakwater in Genoa, Italy
   a. Description of the project
   b. Soil conditions
   c. Typical design and quantities
   d. Methodology
   e. Quality control
3. Conclusions

Ground improvement techniques



Execution methods

- Stone Columns
  - Dynamic Tamping
    - Top Feed
      - Heavy tamping
        - Dynamic Replacement
      - Hammer (hydraulic)
        - Pre-excavation
  - Top vibrator (electric / hydraulic)
    - Top Feed Poker
      - Direct (no air)
        - Leader mast
          - with external sleeve
    - Bottom Feed Poker
      - Direct (no air)
      - w/ air jets
      - w/ Compressed air
        - Leader mast
    - Top Feed Closed casing
      - Direct (no air)
        - Geotextile Coated Columns
    - Bottom Feed Closed casing
      - Direct (no air)
      - w/ Compressed air
      - w/ air jets
        - Cable suspended
        - Excavator suspended
        - Leader mast
      - Sand Compaction pile
        - Leader mast
    - Bottom Feed Slotted casing
      - w/ air jets
      - Direct (no air)
        - Leader mast
  - Bottom vibrator (electric / hydraulic)
    - Top Feed
      - Dry method
        - Cable suspended
        - Excavator suspended
        - Leader mast
      - Wet method (water + air)
        - Cable crane suspended
        - Excavator suspended
        - Leader mast
    - Bottom Feed
      - Dry method
        - Cable crane suspended
        - Excavator suspended
        - Leader mast
          - With water jetting

SOCIEDAD ESPAÑOLA DE MECÁNICA DEL SUELO E INGENIERÍA GEOTÉCNICA

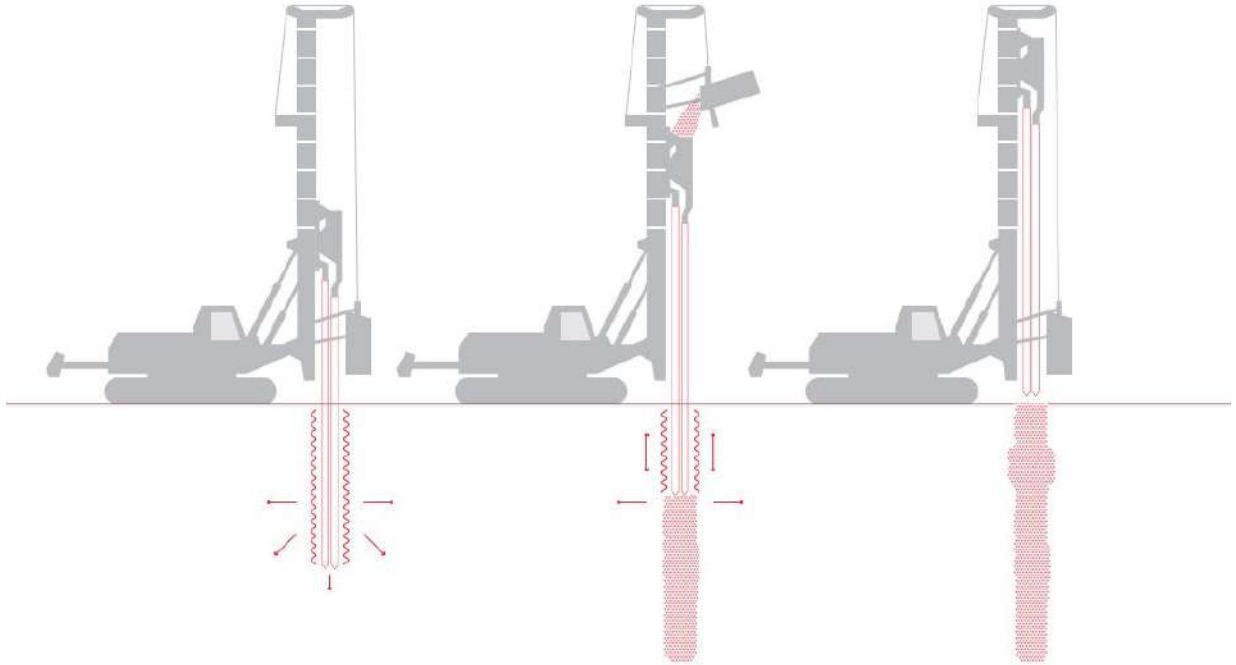
GENOA new breakwater, Italy

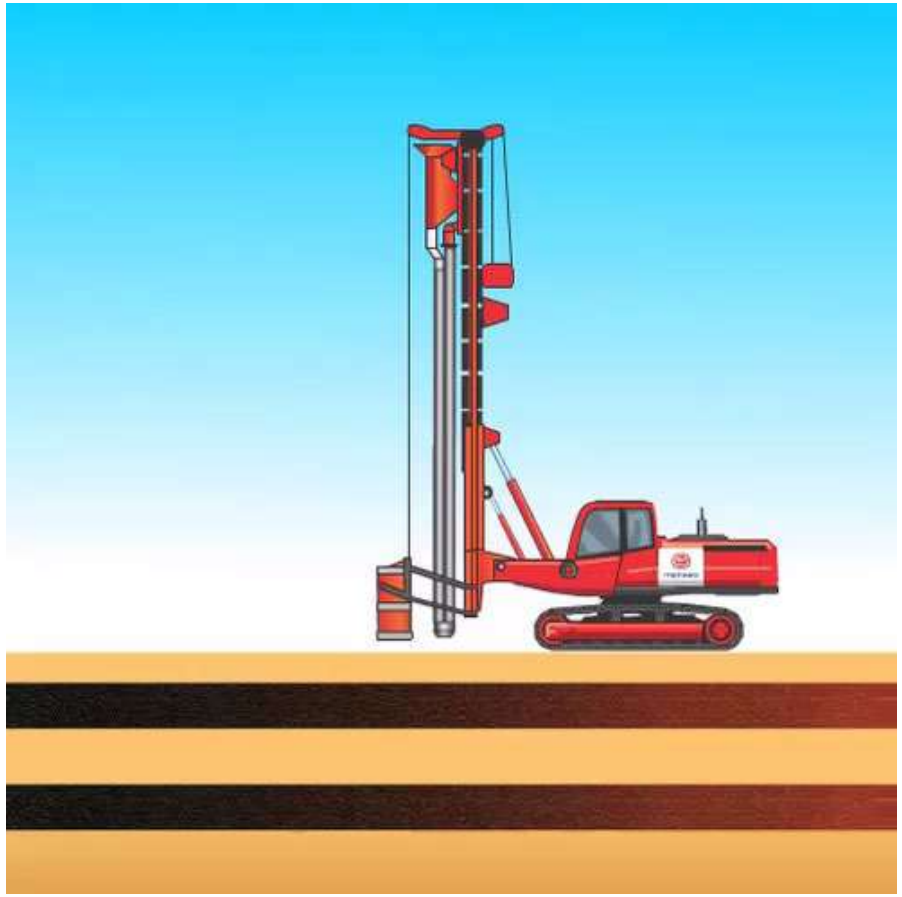
menard

Execution methods

Dry Bottom Feed

Dry method, filling from the base





Execution methods

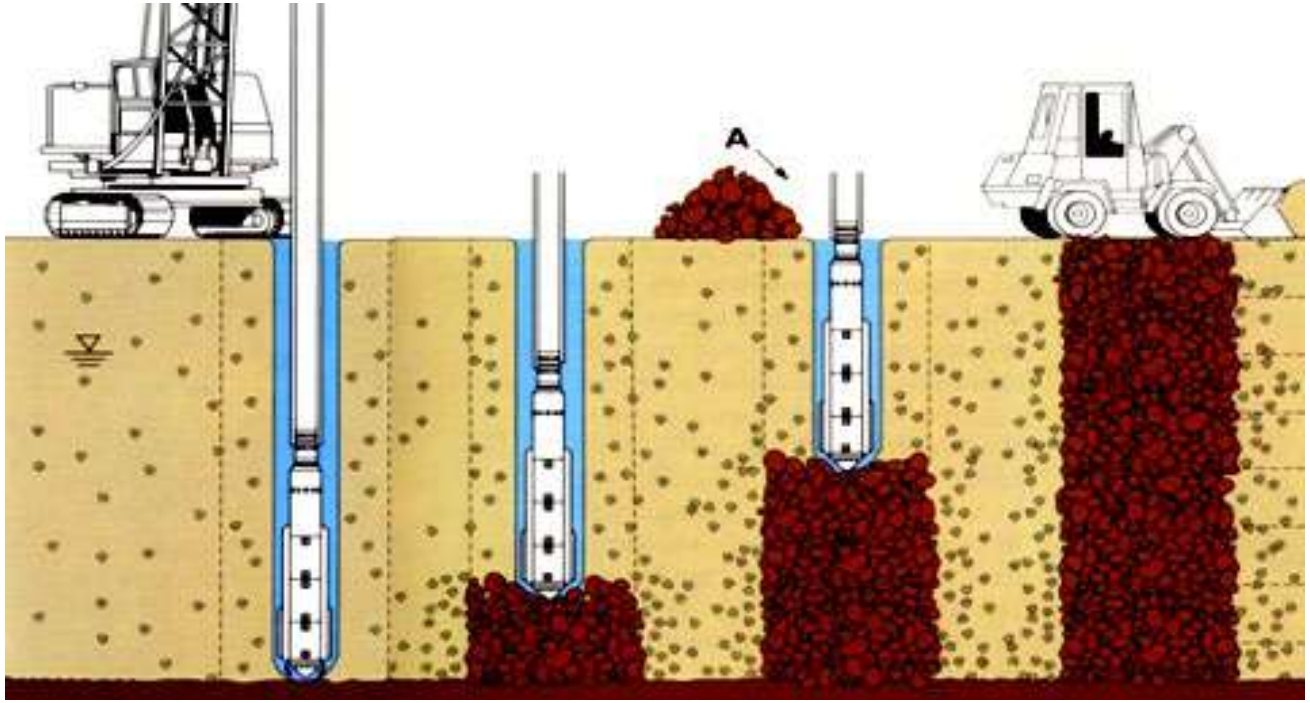
Dry Bottom Feed

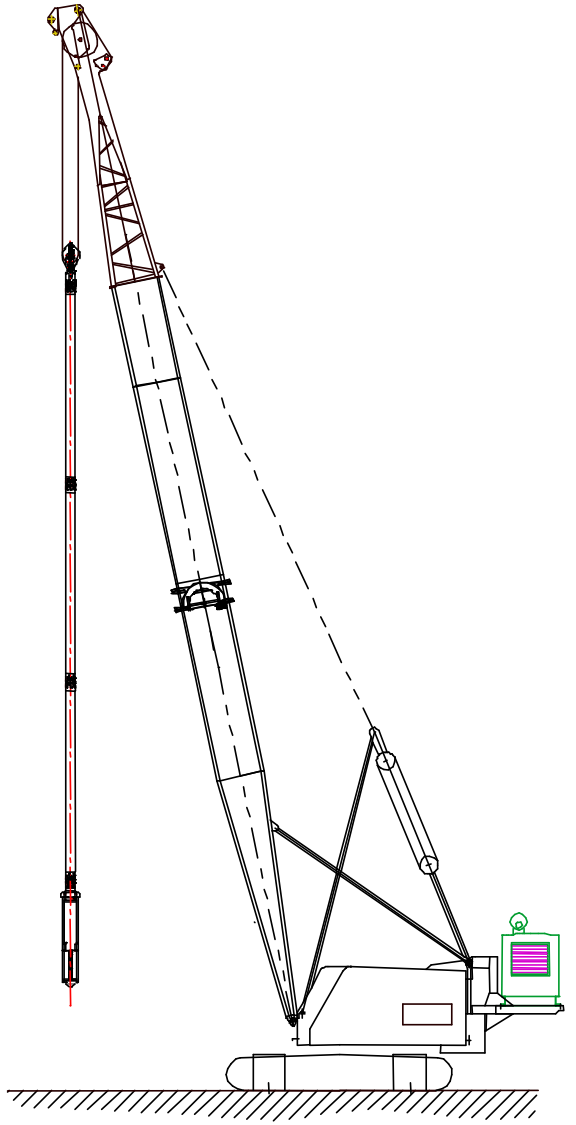
Dry method, filling from the base

Execution methods

Wet Top Feed

Wet method, filling from the top





Execution methods

Wet Top Feed

Wet method, filling from the top

Scope of application and order of magnitude

Objectives

Incorporate compacted granular materials into compressible soils using a vibrator, in order to form flexible inclusions with high mechanical properties and a high drainage capacity.

Order of magnitude

Diameter : 0,50 to 1,20 m
Grid : 1,5 to 3 m (square)
Incorporation ratio: 3 to 25%
Ey = 15 to 100 MPa / c' = 0 / φ' = 35 to 45°
Depth : 2 to 30 m, up to 60 m
Aggregates : 8/40 for Dry Bottom Feed
20/75 for Wet Top Feed
Settlement Reduction Factors : 1,5 to 3

Structures and objectives

Structures/Area	Objectives
Buildings (industrial, commercial, residential, etc.)	**Reduce settlement** of compressible layers while maintaining shallow foundation systems and slabs-on-grade.
Road and railway embankments, and dikes	**Ensure stability** by leveraging the draining nature of the inclusions (in-situ soil consolidation) and the increase in shear strength. → Project example : GENOA new breakwater, Italy
Retaining walls	**Reduce earth pressure** on the retaining structure through improved shear characteristics.
Seismic zone	Anti-liquefaction treatment through **densification, reduction of shear stress,** and **drainage.**

Summary

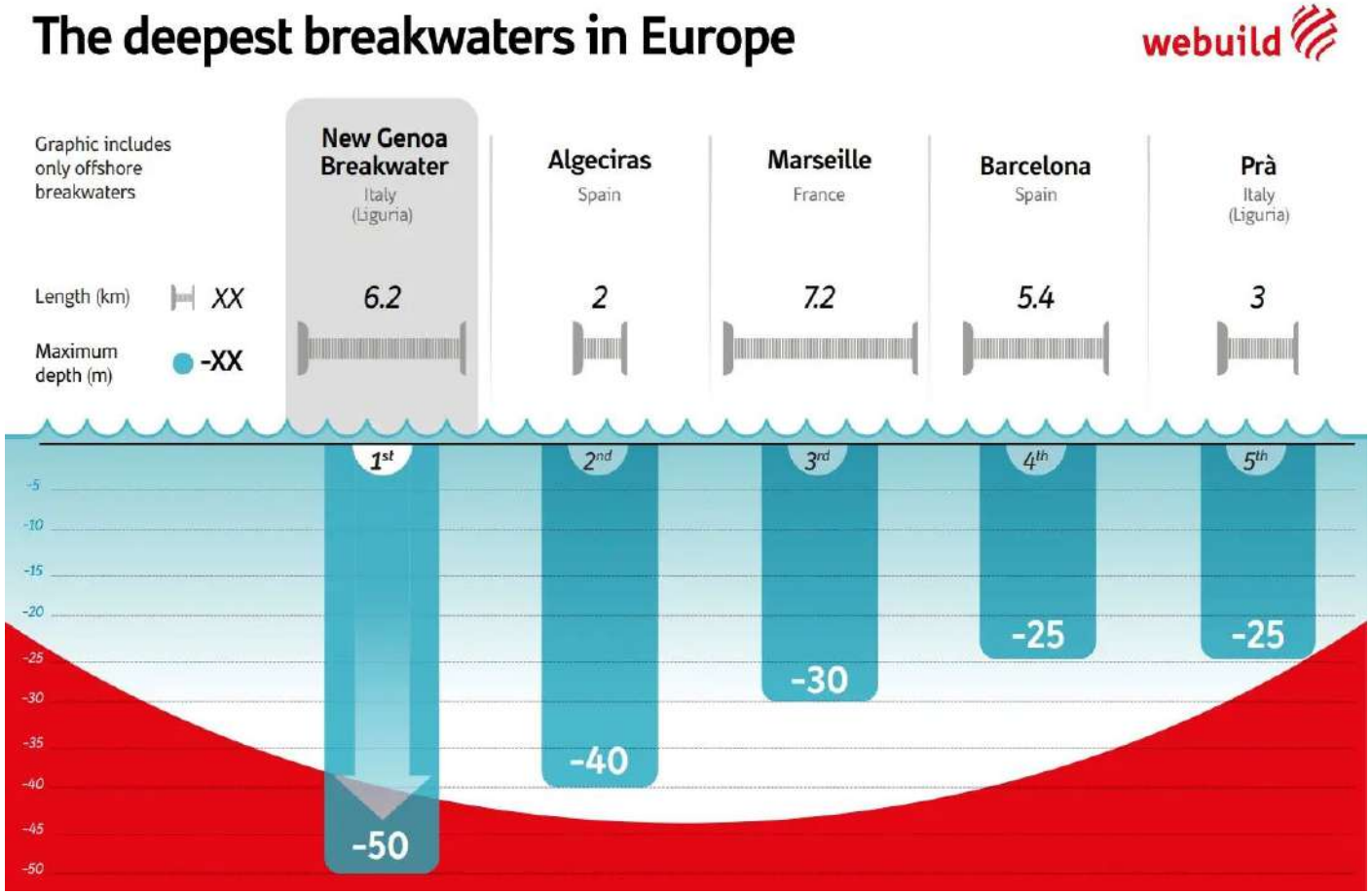
1. Stone Columns – Principles and Practice
   a. Ground improvement techniques
   b. Execution methods
   c. Scope of application
   d. Structures and objectives
2. New breakwater in Genoa, Italy
   a. Description of the project
   b. Soil conditions
   c. Typical design and quantities
   d. Methodology
   e. Quality control
3. Conclusions

Description of the project

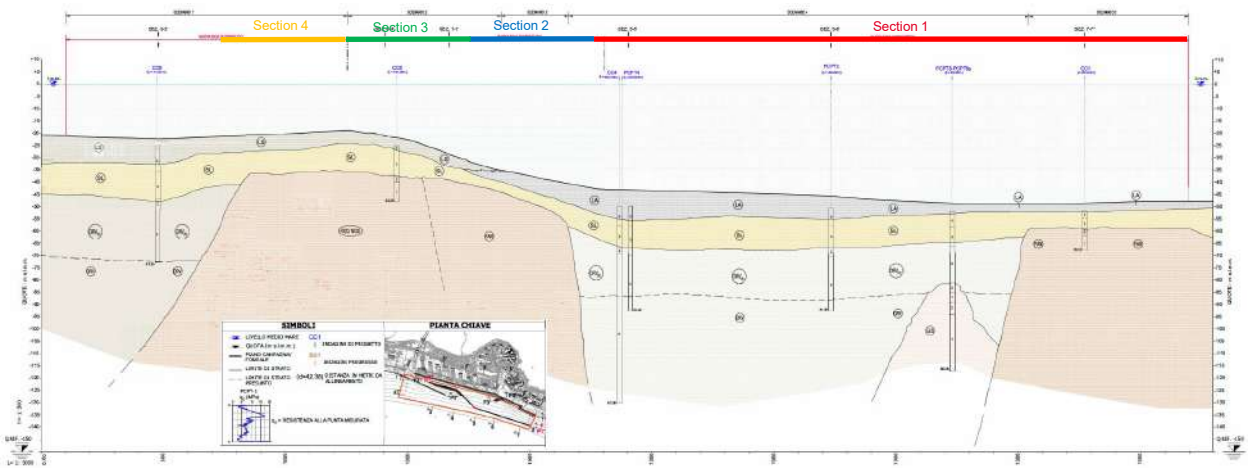
Description of the project

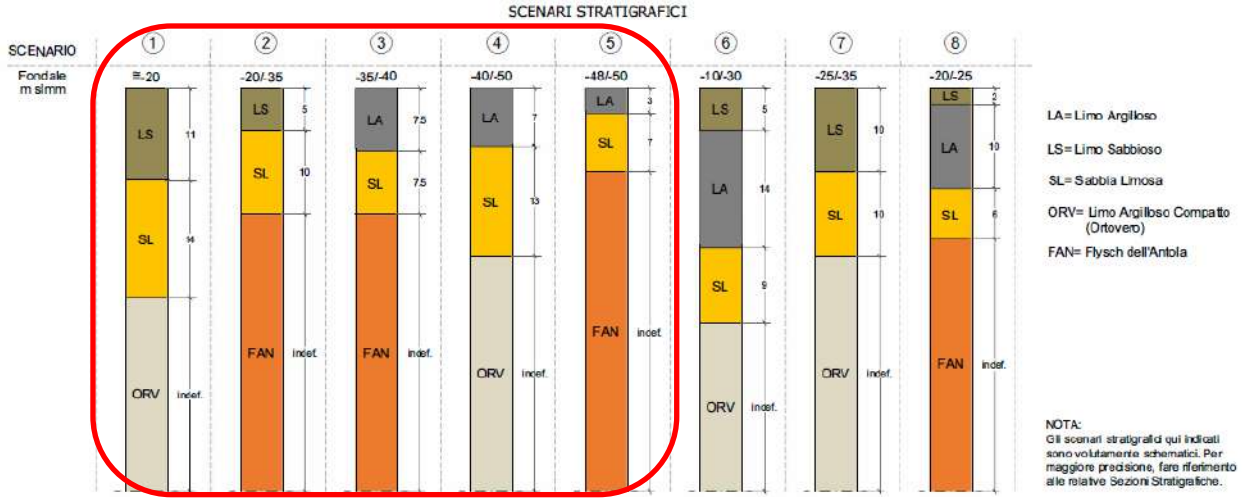
- **Location** : Genoa – ITALY
- **Solution**: Caissons (to -25 msl) on quarry run embankment
- **Water depth** : -25 to -50 msl
- **Depth of soft soil** : 7 to 14 m
- **General Contractor (our client)** :

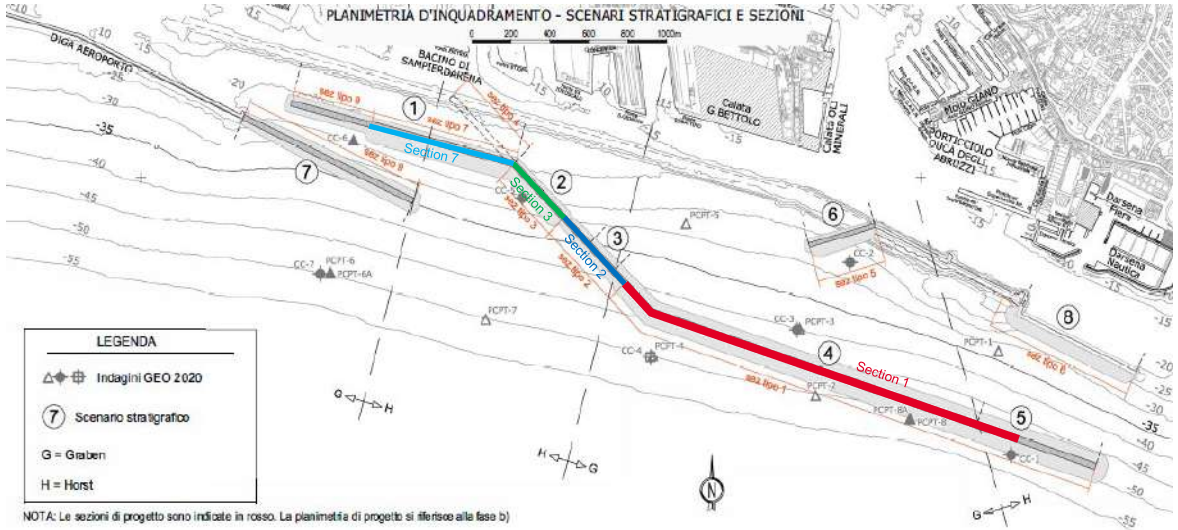
  WEBUILD / FINCANTIERI / FINCOSIT
- **Designer** : RAMBOLL / F&M Ingegneria SpA
- **Contract amount** : 928 mEUR
- **Owner :** West Ligurian Sea Port Authority
- **Designer tender**: Technital

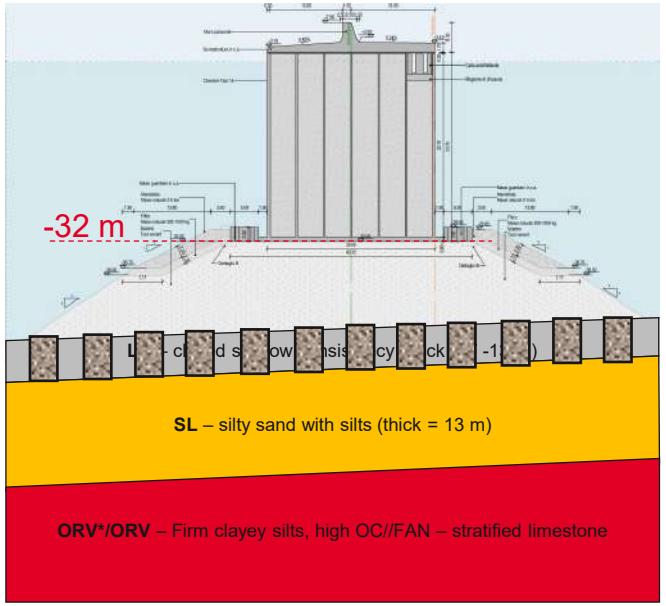


Soil conditions







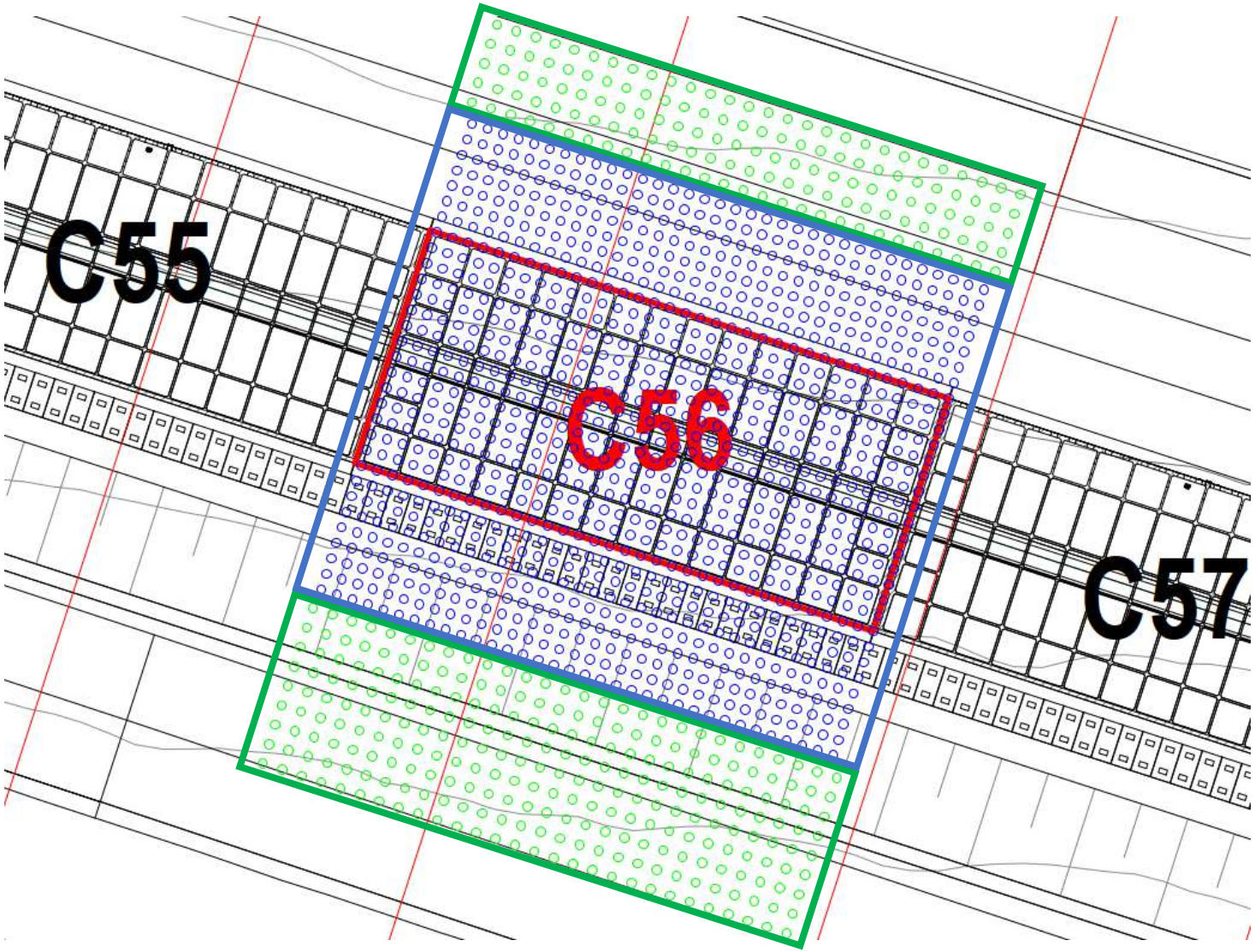


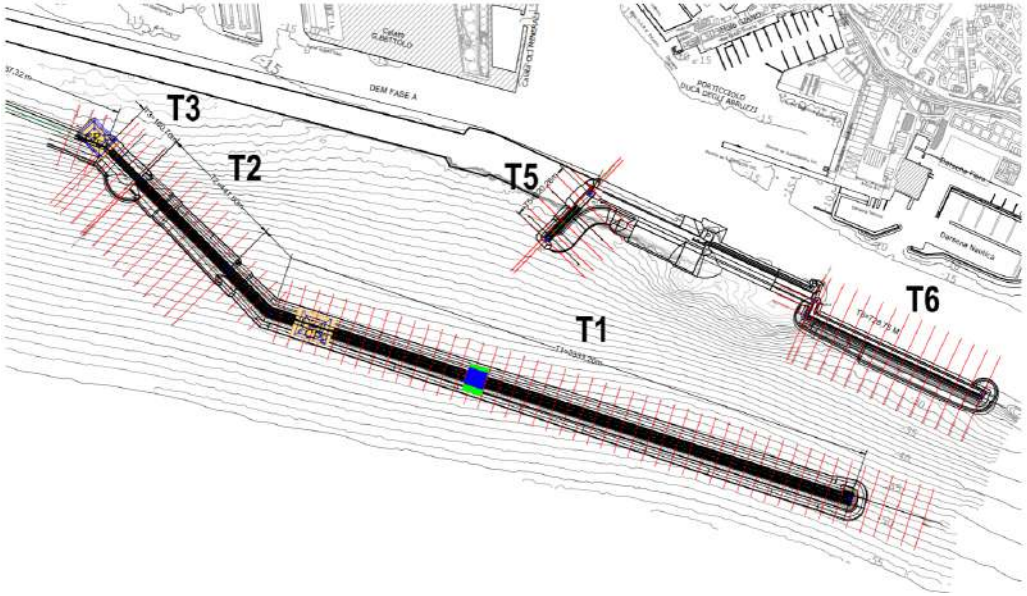
Ground improvement in the superficial soils belonging to the LA and LS units by construction of Stone Columns with the " WET TOP FEED – STONE BLANKET METHOD "

Project Requirements:

- Increase the permeability of the treated soil, so that the resistance behavior is drained even under wave and cyclic loads or with the induction of neutral overpressures that do not generate stability problems in any load condition
- Increase the characteristics of drained shear resistance, in terms of friction angle and cohesion
- Reduce the deformability of the soil-column complex, with a consequent reduction of induced settlements that will occur during construction, without primary consolidation queues, as well as substantial reduction and / or elimination of the interpenetration problem during installation.

Typical design





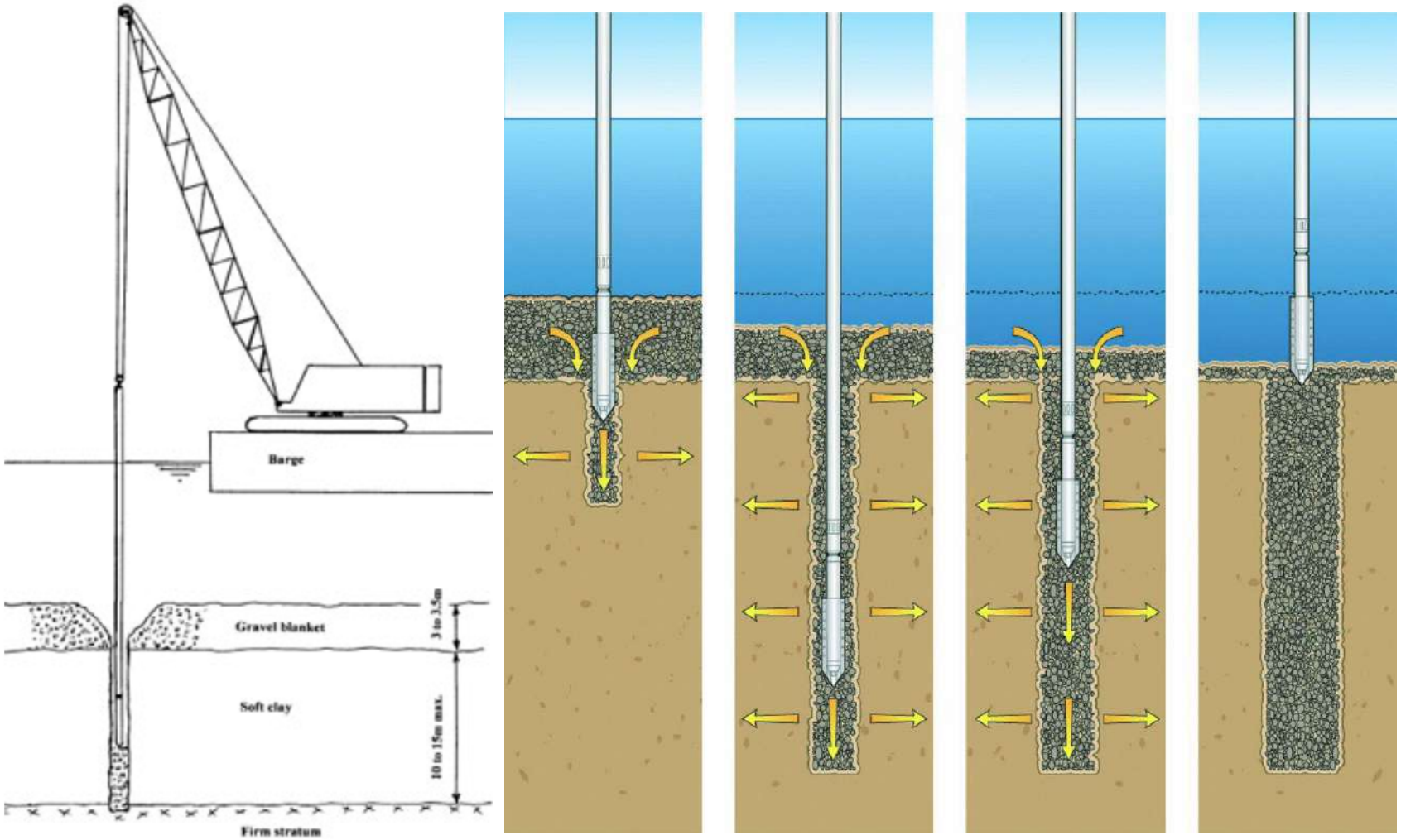
For GENERAL CONTRACTOR, Design & Built with design by Consortium design JV

For MENARD, **Built only and measurable quantity basis**

Design requirements for the Vibro Stone Columns (Section 1 to 4) are the following (Optimized design by GC):

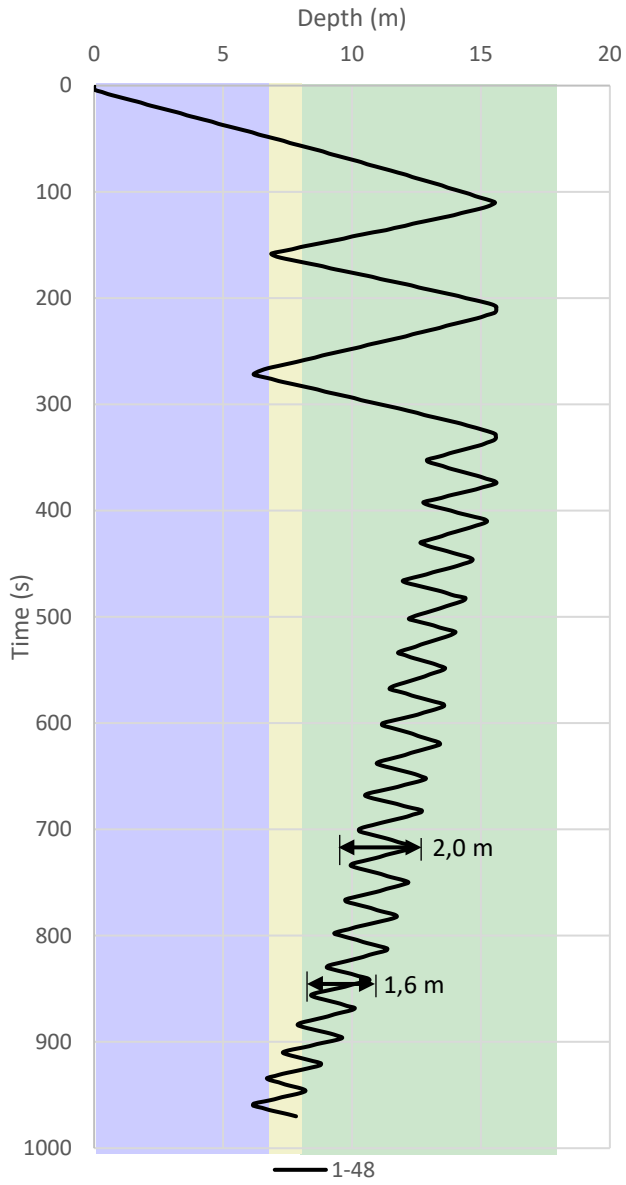
- In soil type LA (for section 1 & 2): "Incorporation ratio" of **15,2%** to **23,7%**, corresponding to diameter **1,1 m** and square grid spacing **of 2m in center** part of the embankment **and 2,5m on edges**,
- In soil type LS: "Incorporation ratio" **10,5%**, corresponding to diameter 1,1 m and square grid spacing of 3 m

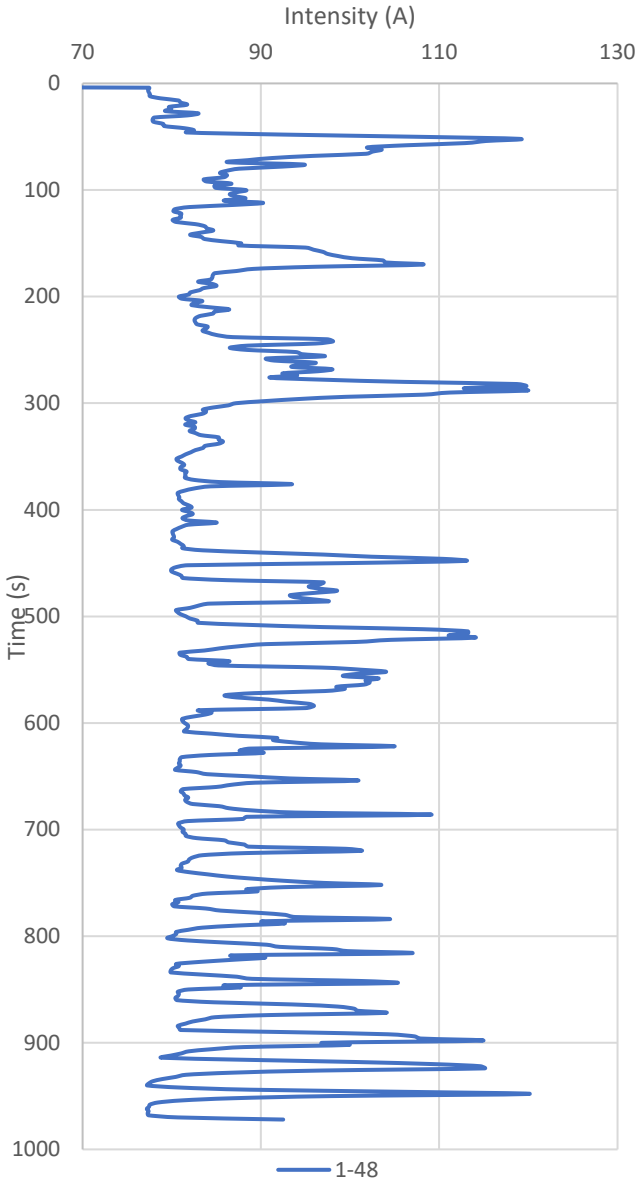
Method : Off-shore Stone Columns : Wet Top Feed Stone Blanket method

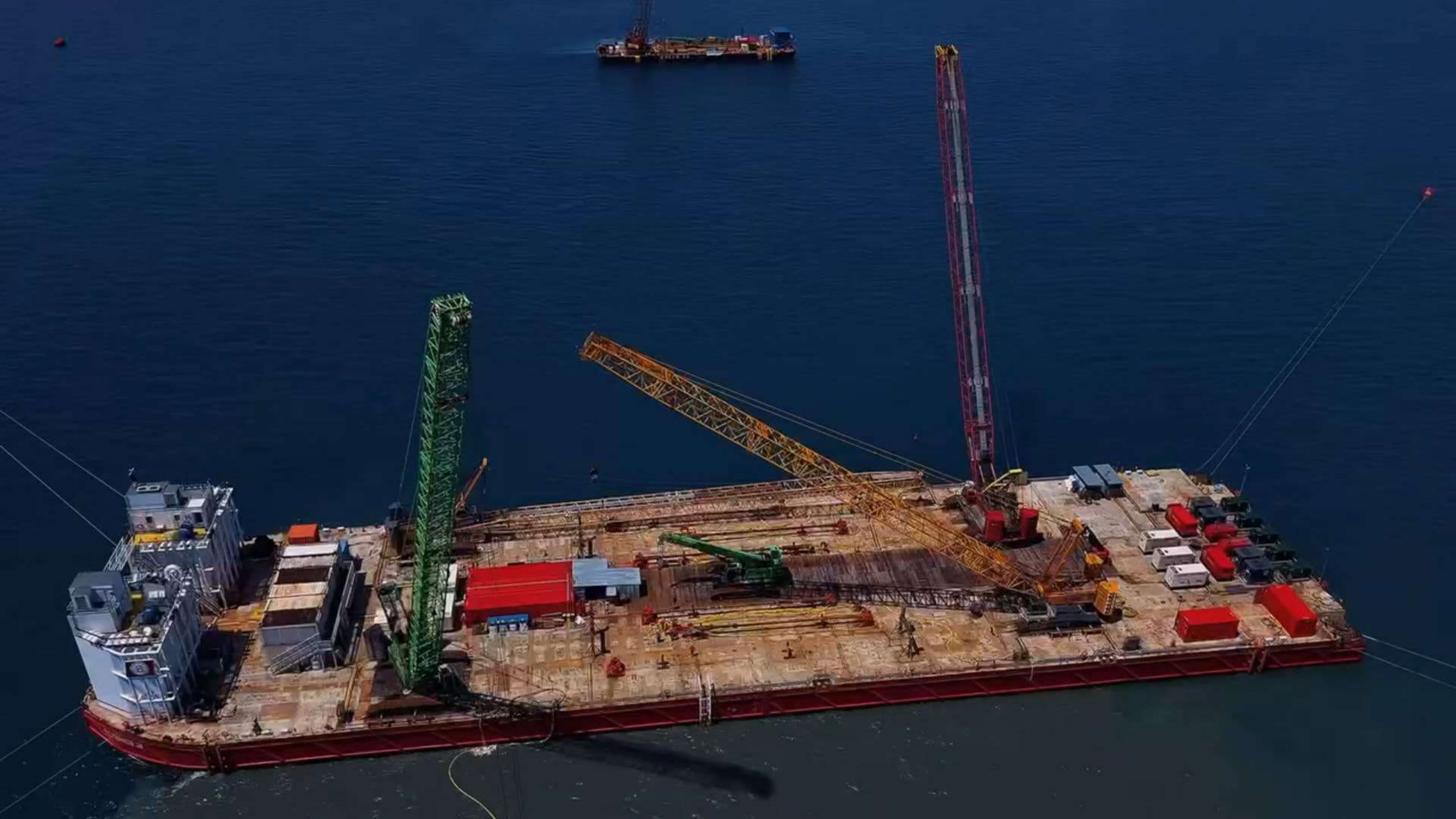


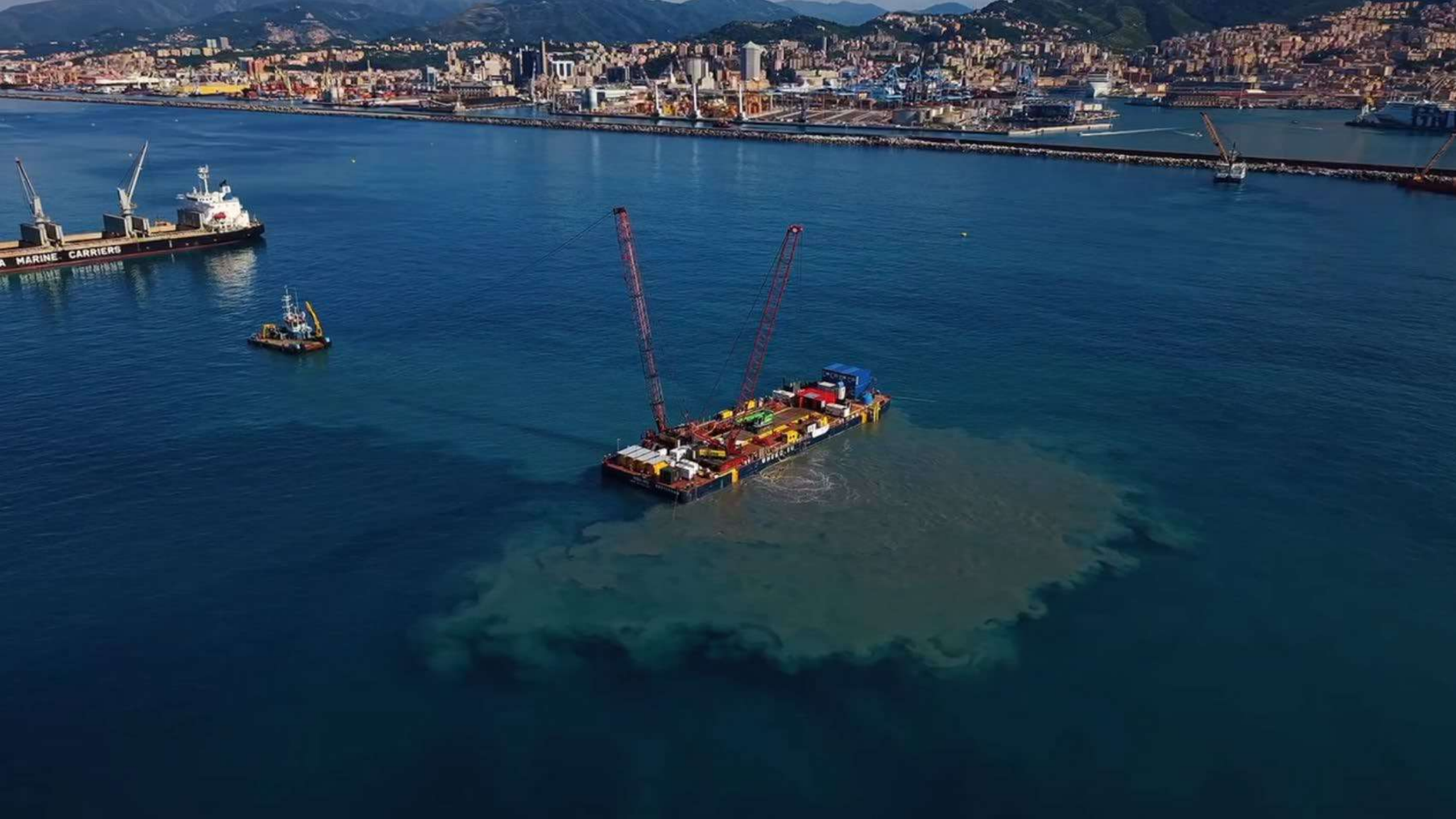
Methodology

- 2 to 3 complete flushings (up & down) to create an annular spacing around the vibrator to allow the stone to “fall” to the bottom.
- lifting steps (about 2 m) to allow the stone to fall into the gap.
- Re-penetration steps (about 1,6m) to compact the stone and expand the diameter.







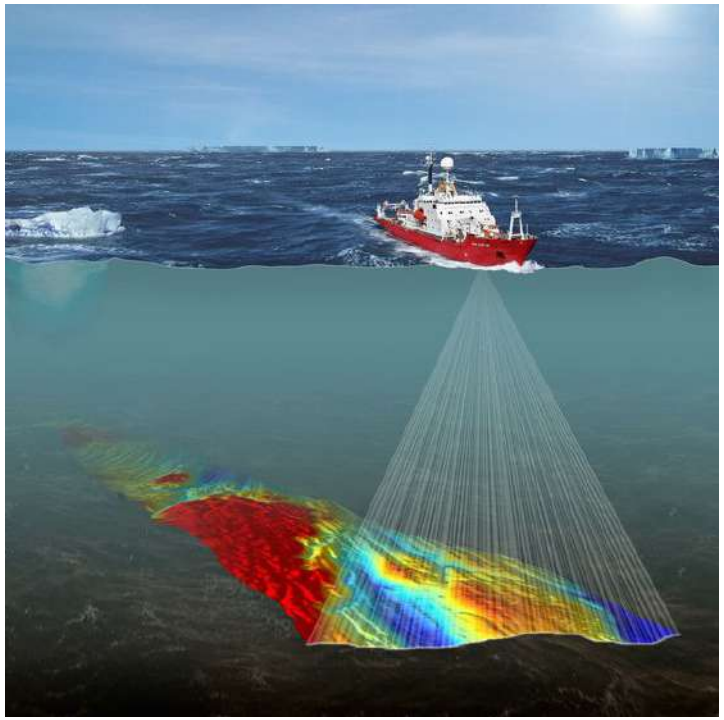

MARINE CARRIERS

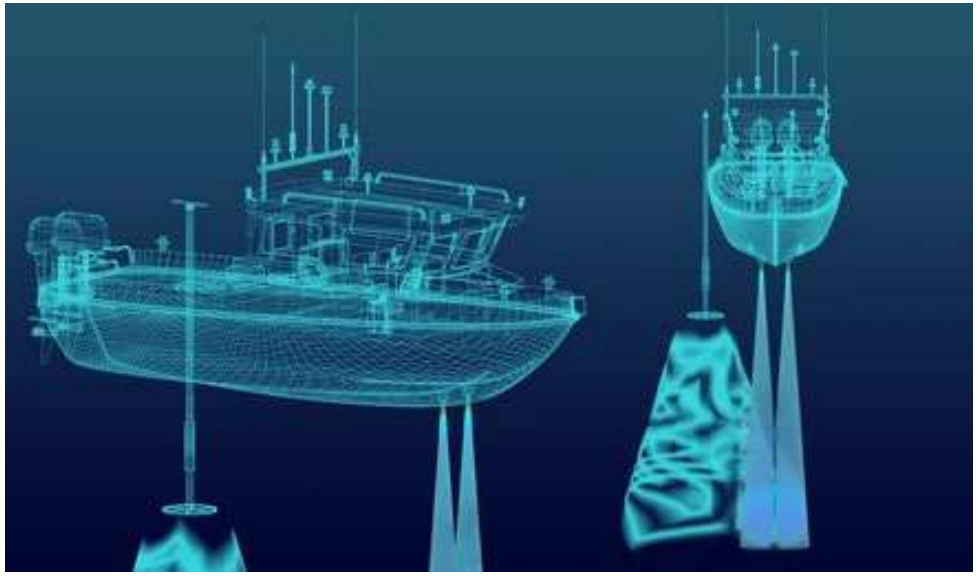

NOVA MARINE CARRIERS

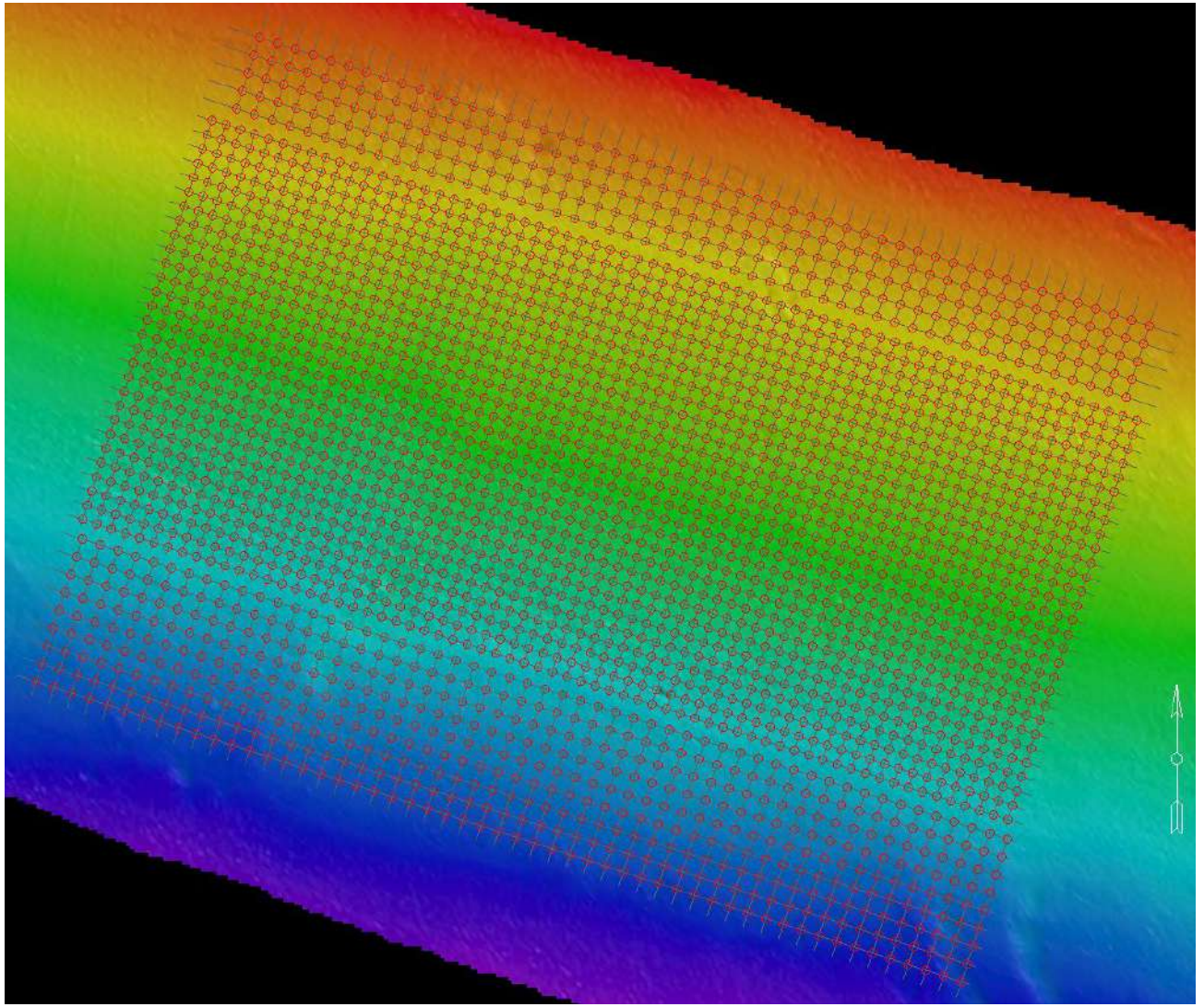
Summary

1. Stone Columns – Principles and Practice
   a. Ground improvement techniques
   b. Execution methods
   c. Scope of application
   d. Structures and objectives
2. New breakwater in Genoa, Italy
   a. Description of the project
   b. Soil conditions
   c. Typical design and quantities
   d. Methodology
   e. Quality control
3. Conclusions

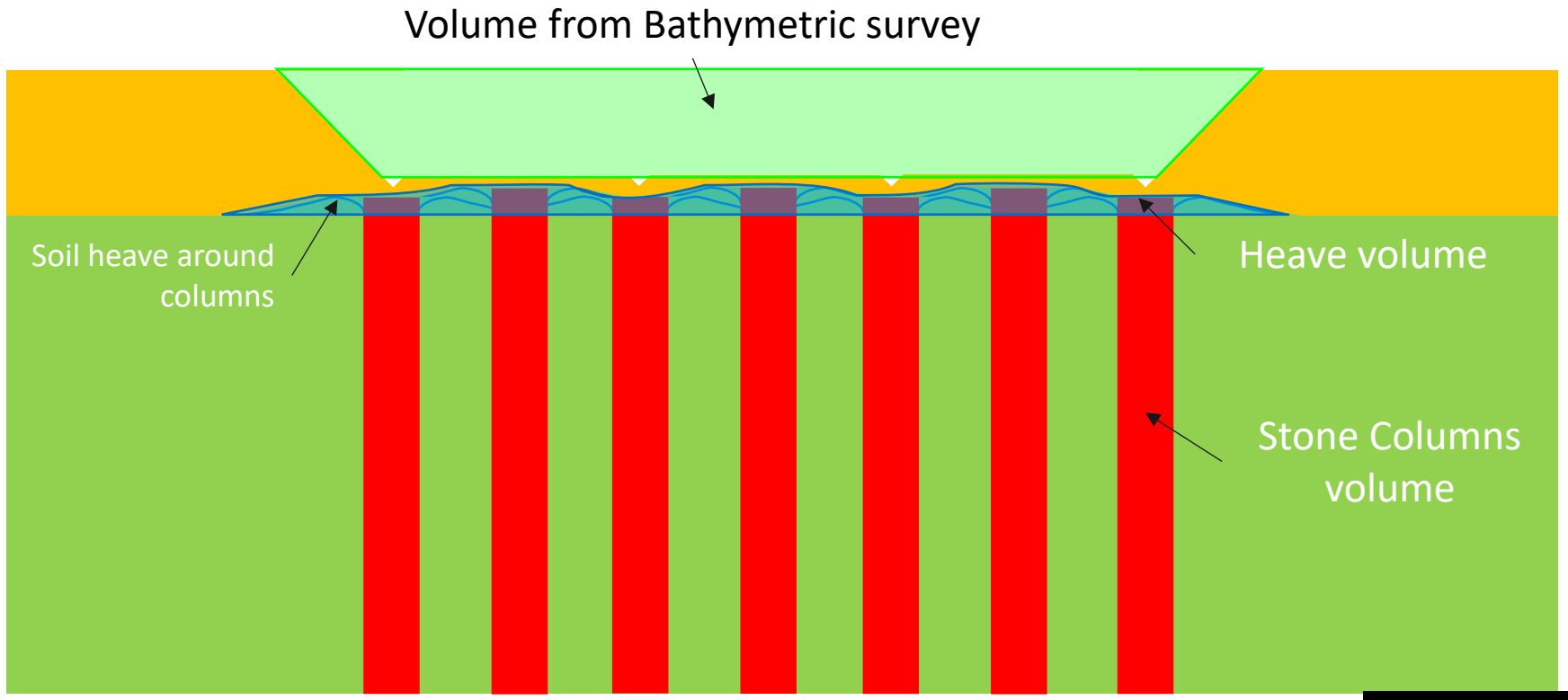
The bathymetry







Analysis of the bathymetric volume

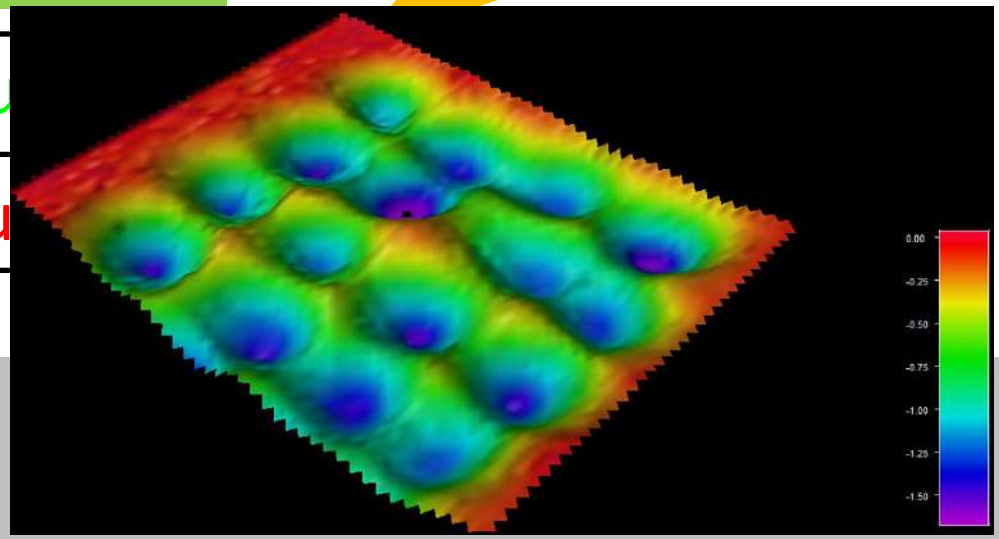


- Installation of Stone columns creates ground heave
- For large areas with close c/c spacing (high replacement ratio), the volume measured from bathymetric survey is impacted by ground heave

Calibrated to a pourcentage of incorporated volume during trial test area

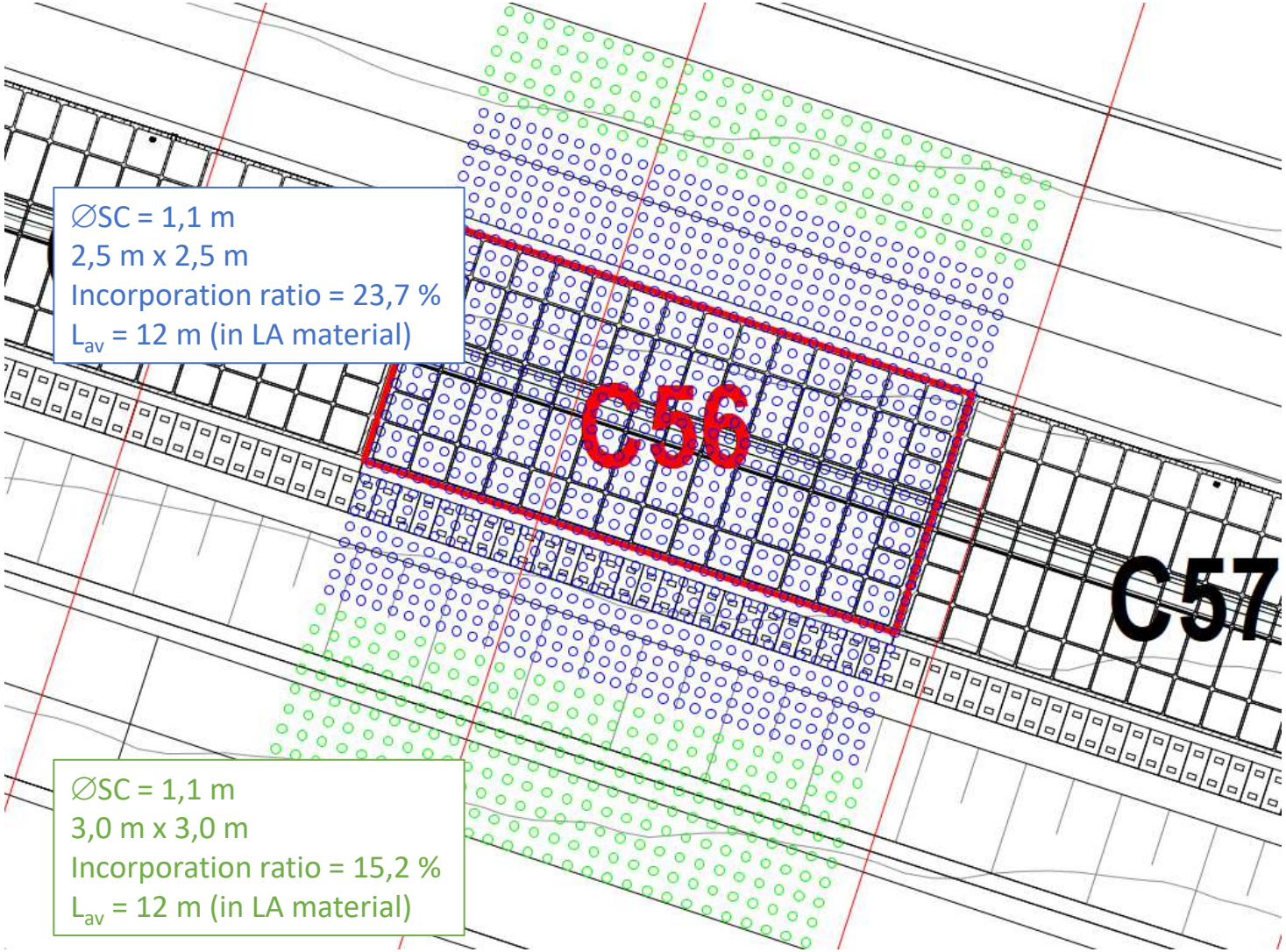
$$\text{Stone Columns volume} = \frac{\text{Bathymetric volu}}{1+\text{Bu}}$$

Calibrated during trial test area



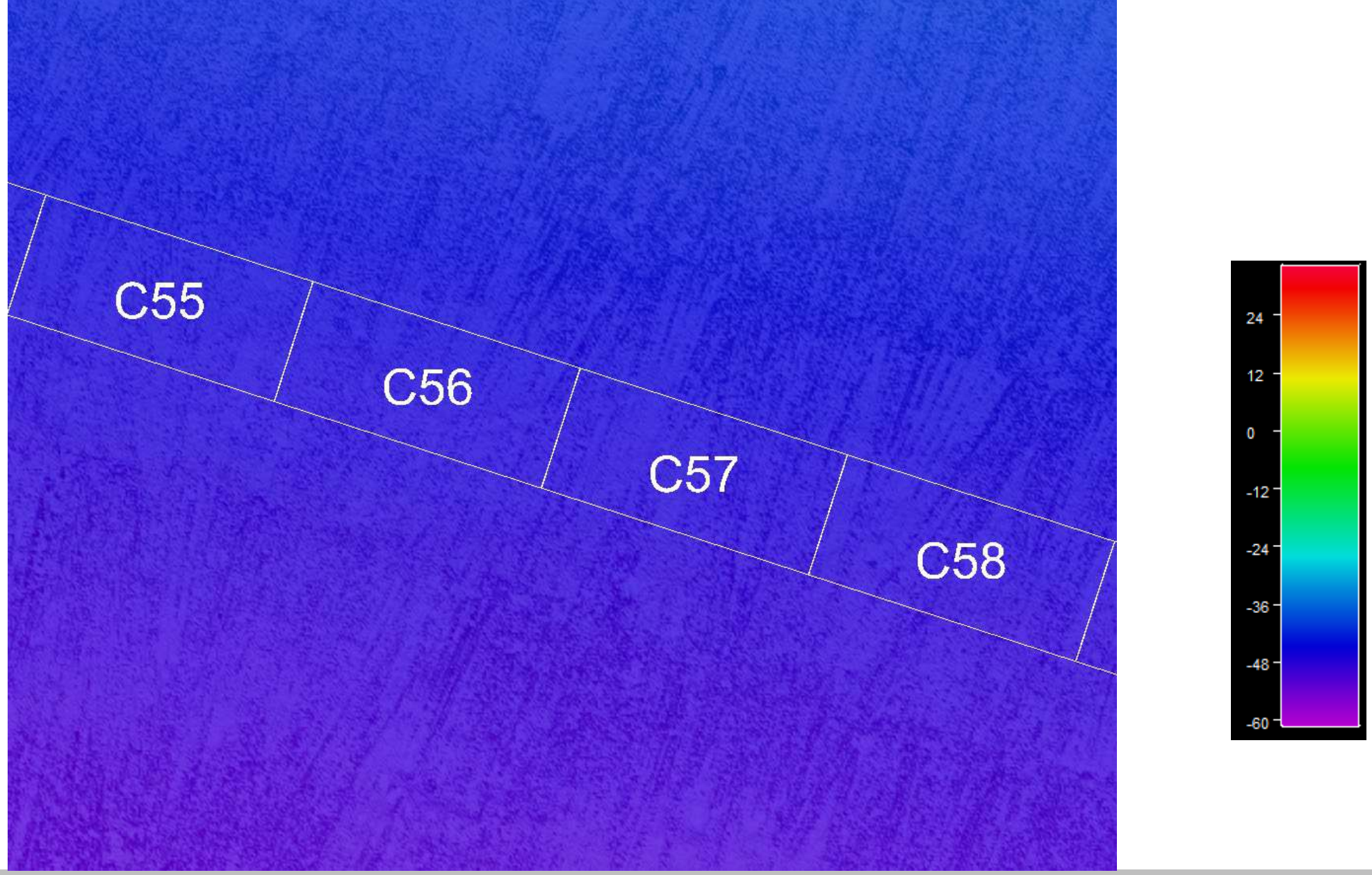
GENOA new breakwater, Italy

Quality control for caisson C56



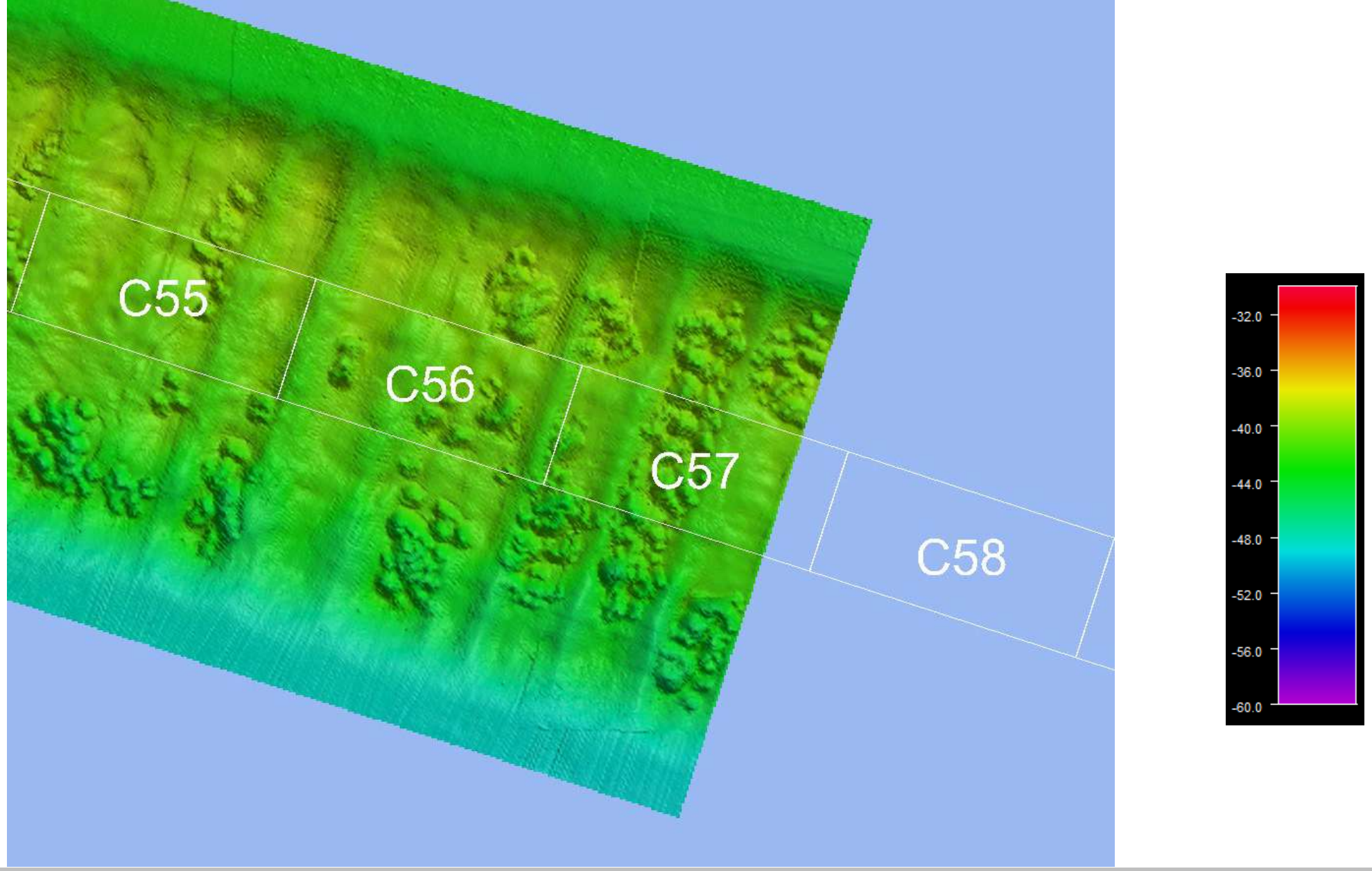
T1 Caisson C56

Bathymetry of seabed before installation of the Stone Blanket



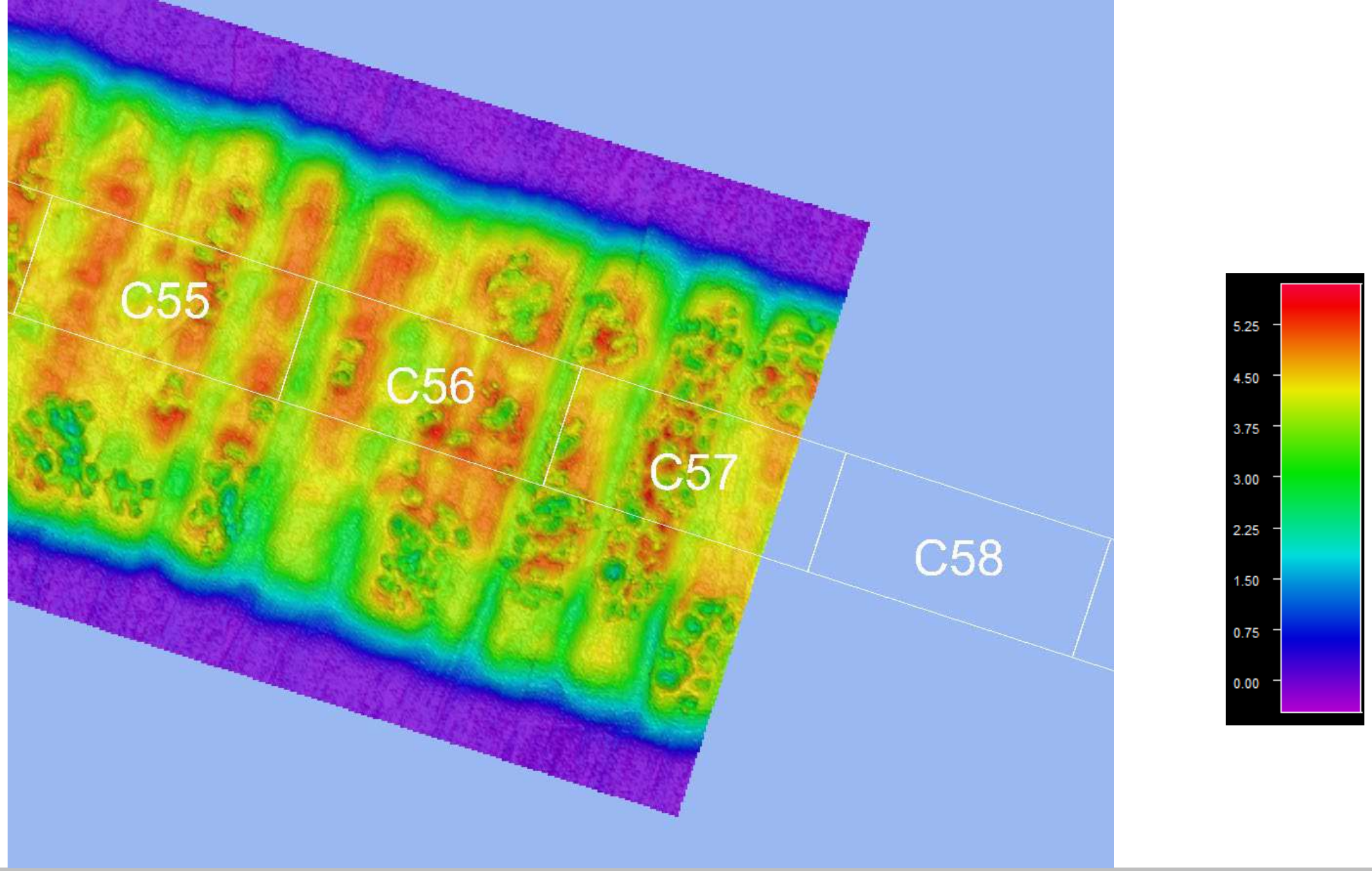
T1 Caisson C56

Bathymetry of seabed after installation of the Stone Blanket



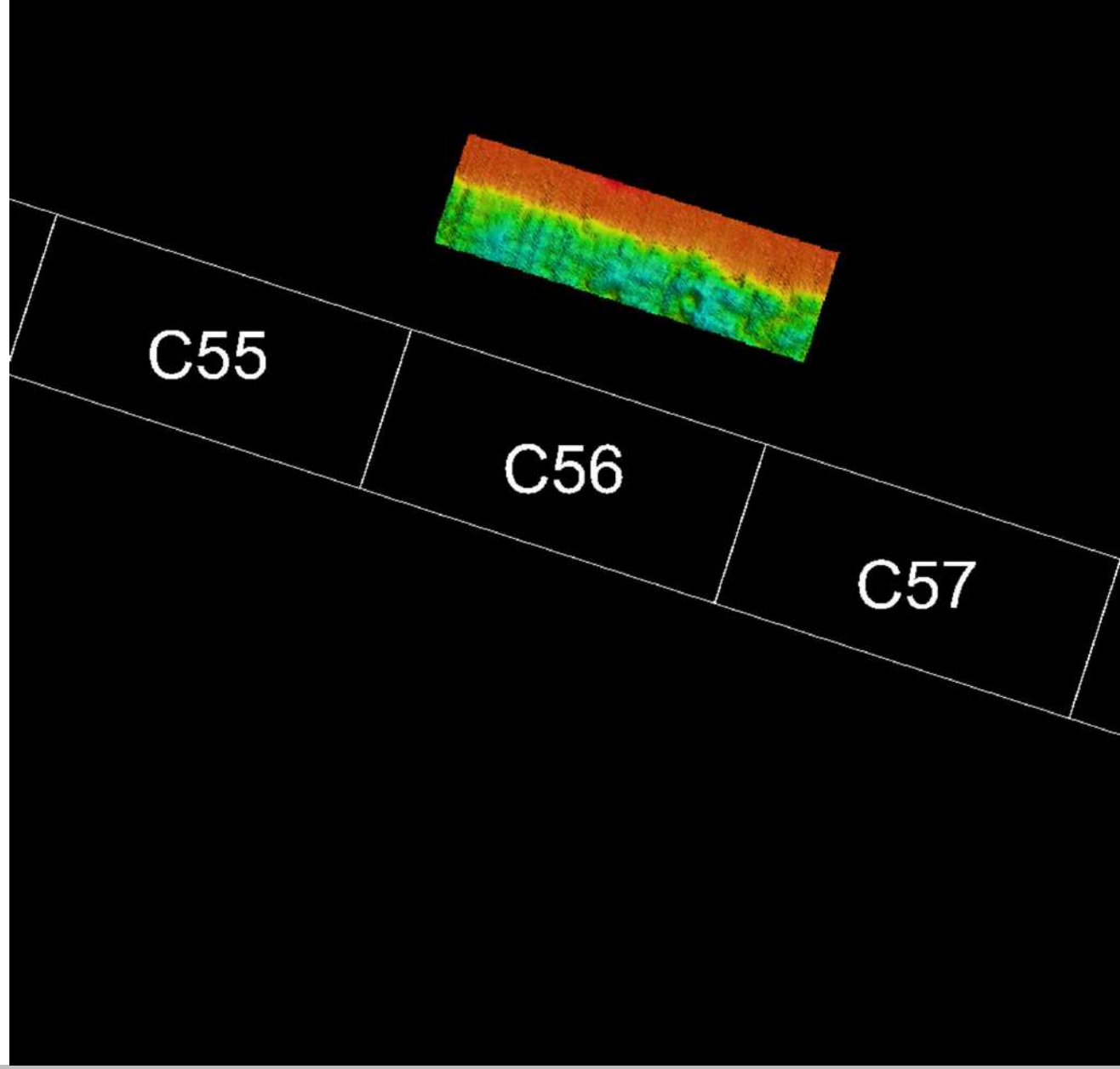
T1 Caisson C56

Thickness of the Stone Blanket



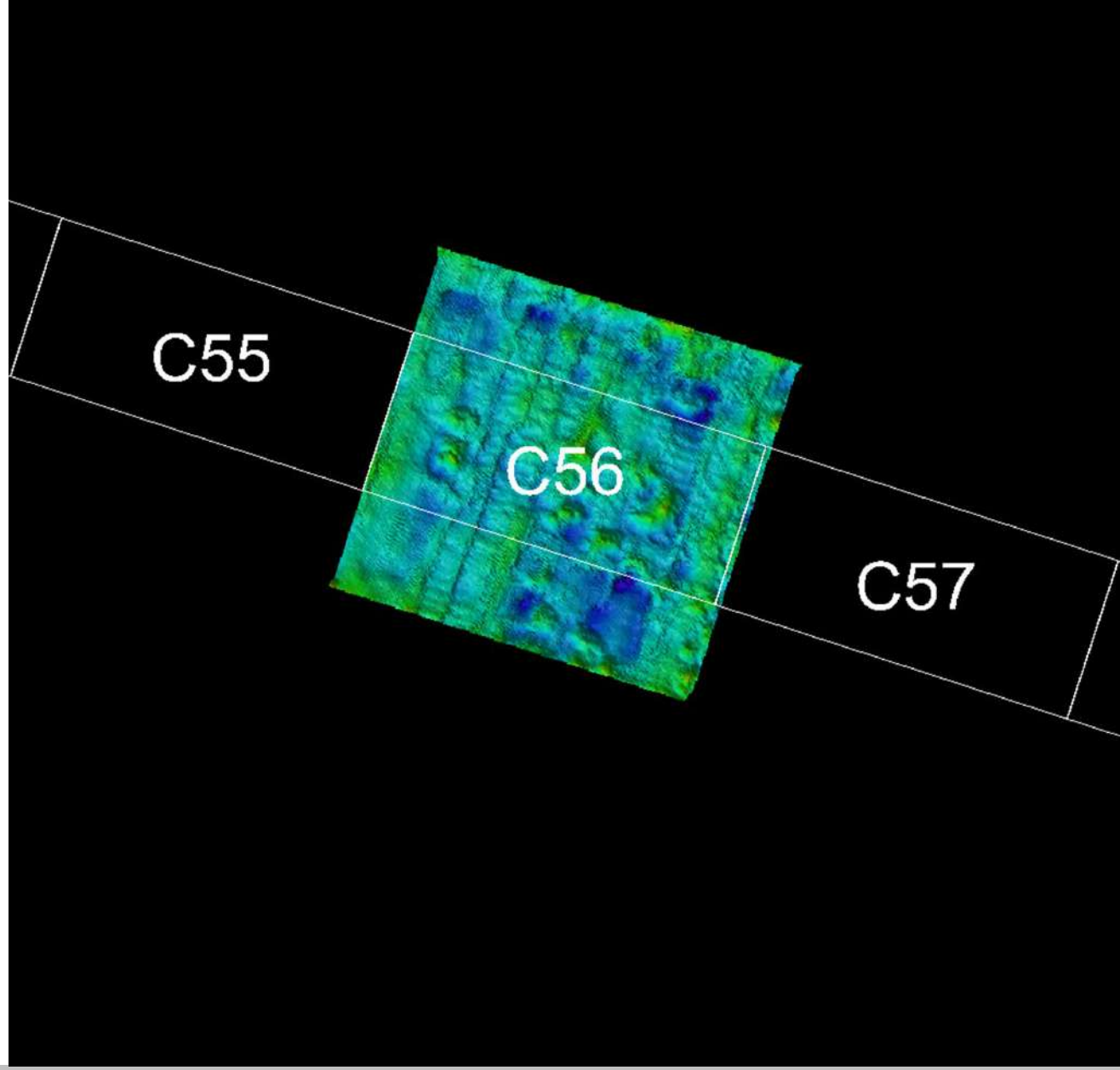
T1 Caisson C56 – 1

Parameter		
Initial bathymetry	24/06/2024	
Final bathymetry	04/08/2025	
Number of Stone Columns	2,5m x 2,5m	140u
Grid surface	6,25 m^2	
Total length of Stone Columns	1697,3 ml	
Area considered	1438,3 m^2	
Volume survey	1651,9 m^3	
Bulk / Heave factor	As calibrated	
Replacement ratio Target	15,21%	
Replacement ratio As-Built	18,54%	



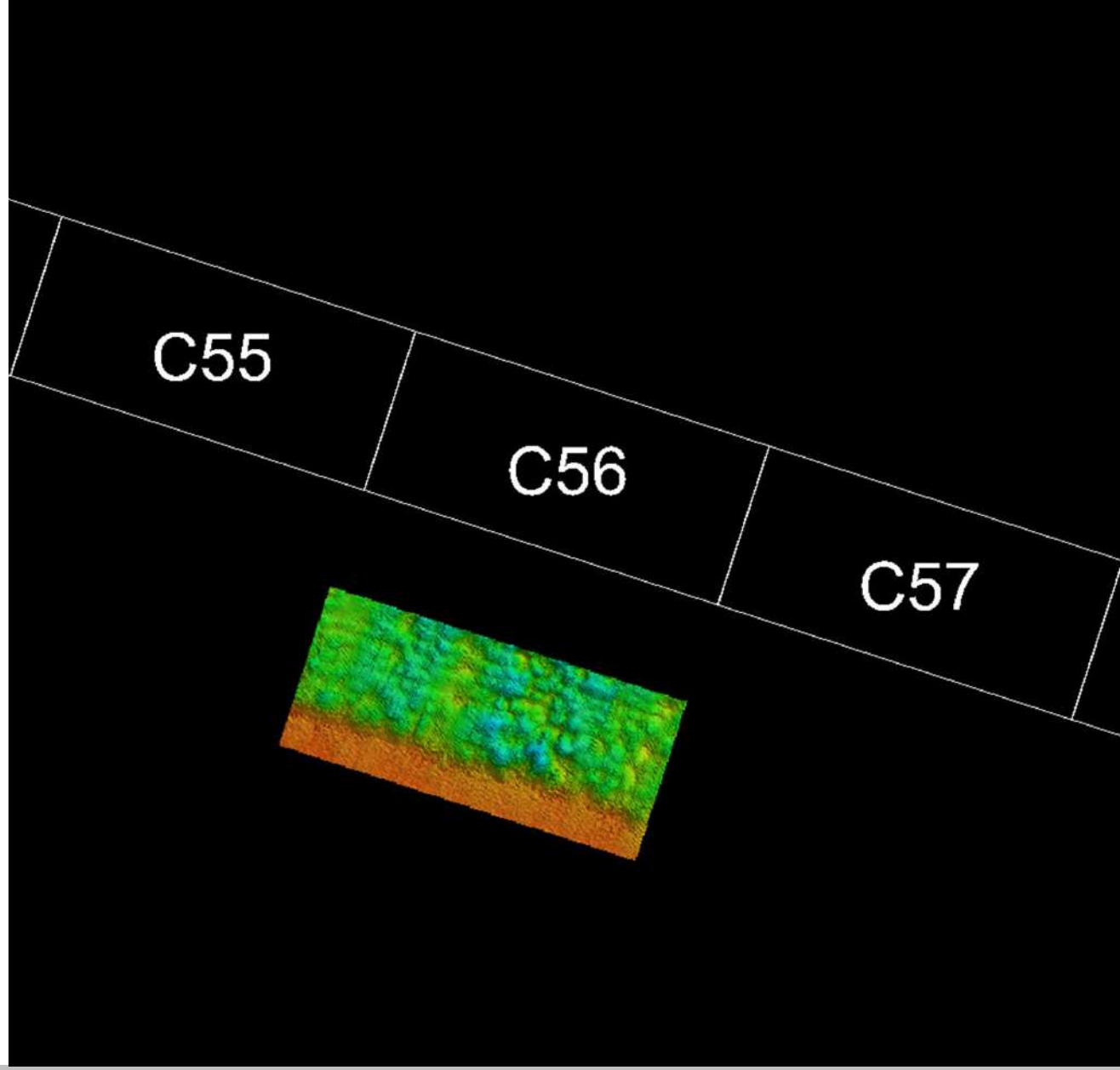
T1 Caisson C56 – 2

Parameter		
Initial bathymetry	24/06/2024	
Final bathymetry	04/08/2025	
Number of Stone Columns	2,0m x 2,0m	1054u
Grid surface	4,00 m^2	
Total length of Stone Columns	12766,3 ml	
Area considered	4383,5 m^2	
Volume survey	11377,5 m^3	
Bulk / Heave factor	As calibrated	
Replacement ratio Target	23,76%	
Replacement ratio As-Built	26,52%	



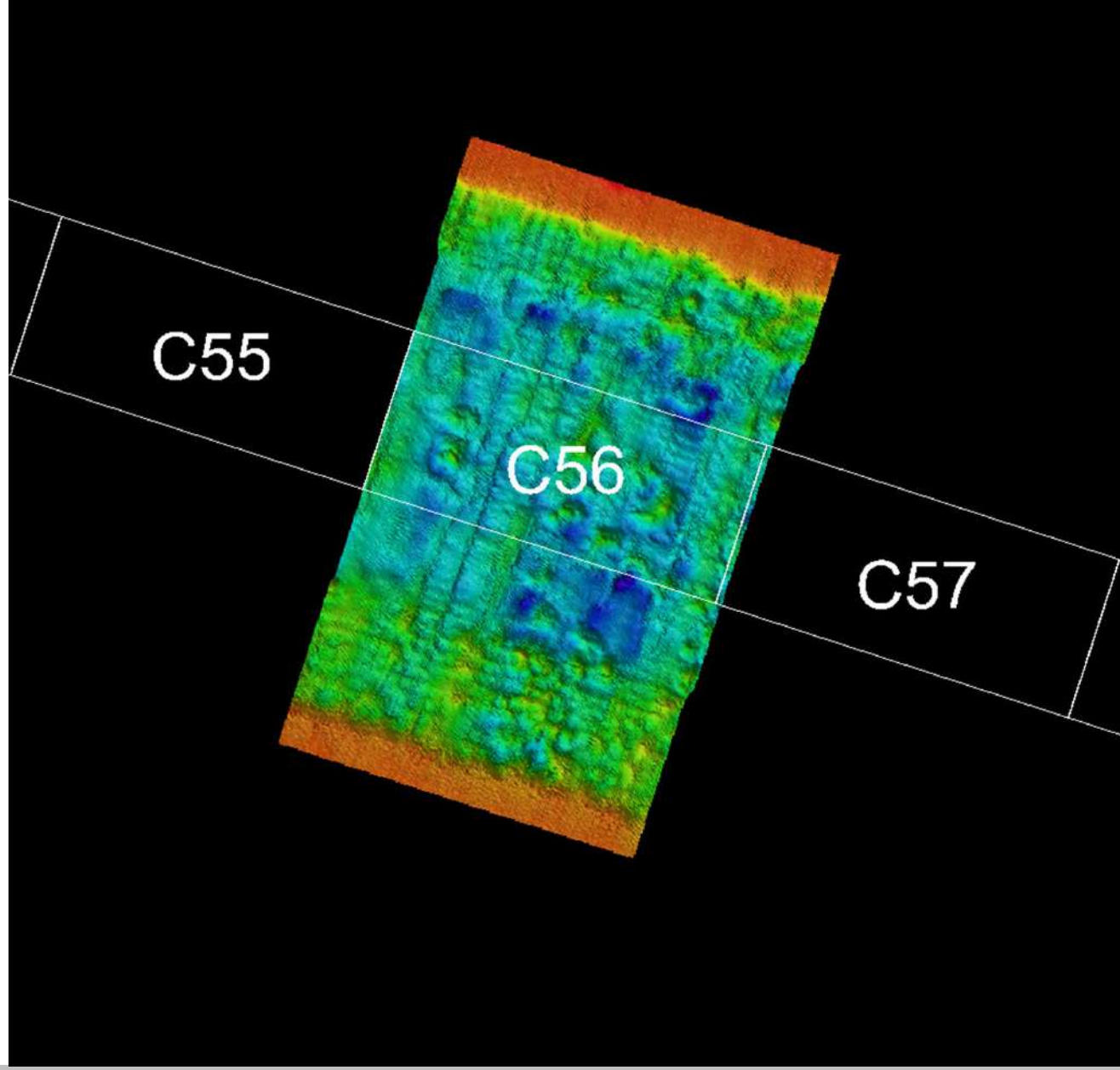
T1 Caisson C56 – 3

Parameter		
Initial bathymetry	24/06/2024	
Final bathymetry	04/08/2025	
Number of Stone Columns	2,5m x 2,5m	243u
Grid surface	6,25 m^2	
Total length of Stone Columns	2942,5 ml	
Area considered	2025,1 m^2	
Volume survey	2755,6 m^3	
Bulk / Heave factor	As calibrated	
Replacement ratio Target	15,21%	
Replacement ratio As-Built	17,84%	



T1 Caisson C56

Parameter		
Initial bathymetry	24/06/2024	
Final bathymetry	04/08/2025	
Number of Stone Columns	2,5m x 2,5m	383u
	2,0m x 2,0m	1054u
	Total	1437u
Equivalent grid surface	4,60 m^2	
Total length of Stone Columns	17406,1 ml	
Area considered	7846,8 m^2	
Volume survey	15785,1 m^3	
Bulk / Heave factor	As calibrated	
Replacement ratio Target	20,66 %	
Replacement ratio As-Built	23,47 %	



Conclusions

- There are **many methods** for installing stone columns.

- Stone columns are well suited to **reducing settlement** (SRF from 1.5 to 3), **increasing shear strength** (and therefore bearing capacity and stability), and **draining the soil** (accelerating consolidation under static conditions and promoting drained behaviour under dynamic conditions).

- **Offshore wet top-feed stone columns**, using **the stone blanket method**, have been (are still being) successfully implemented to support the new iconic Genoa breakwater in Italy.

- Quality control relies solely on **bathymetric surveys**. Trial test areas were first carried out to calibrate the bulk factor and the heave factor in order to accurately interpret the bathymetric results and to make sure that **the targeted incorporation ratio are achieved**.