PIANC French Section

PIANC Mediterranean Days

and Conference «Port of the future» by Cerema

25 to 27 october 2023 in Sete France

Vibro-Replacement technique for the seabed of Salerno port

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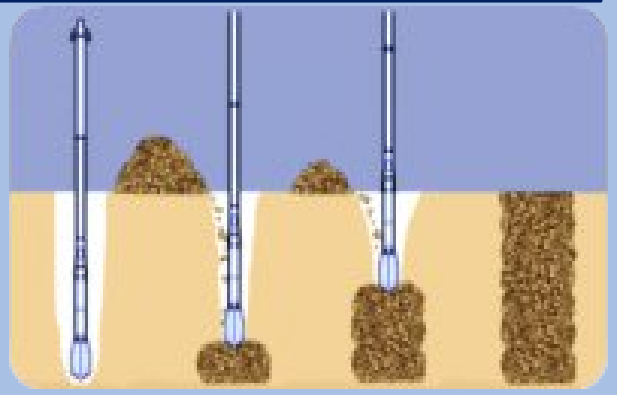
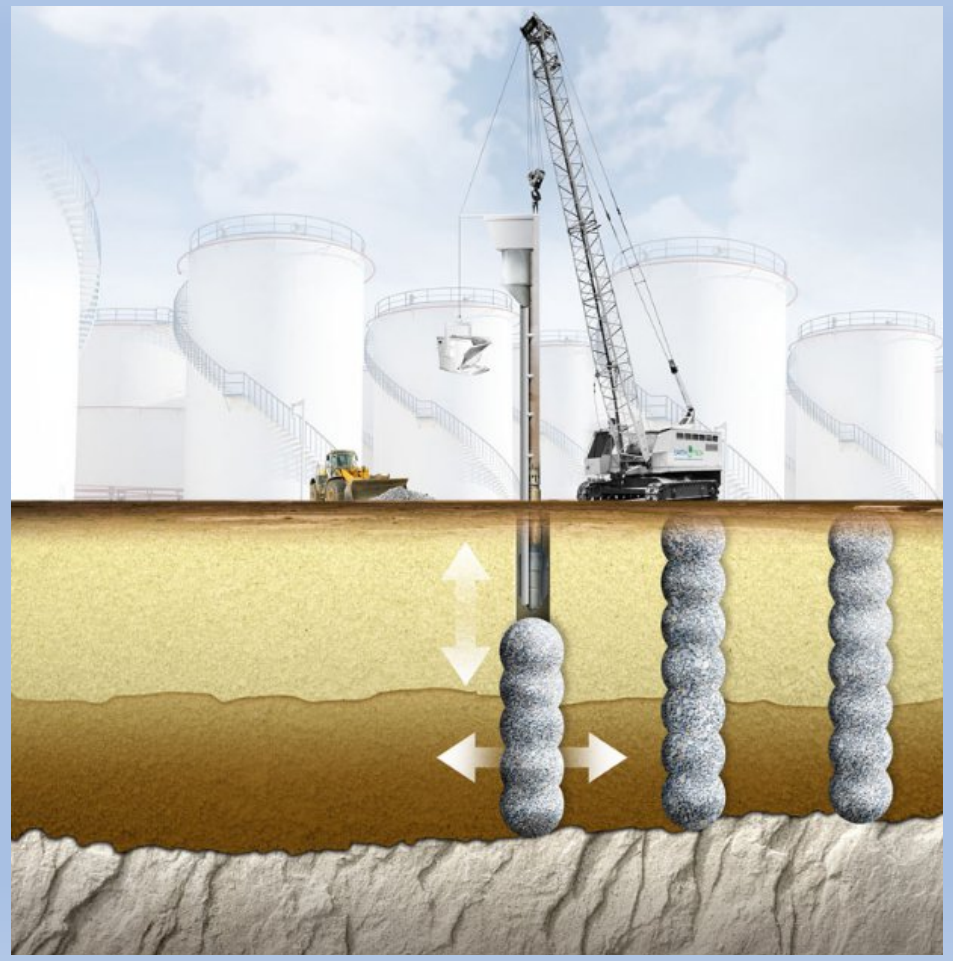
A GENERAL OVERVIEW OF VIBRO-REPLACEMENT TECHNIQUES

Vibro Replacement is the process of **densifying granular soils and reinforcing cohesive soils** with stone columns constructed with the use of specialty down the hole Vibro-Probes.

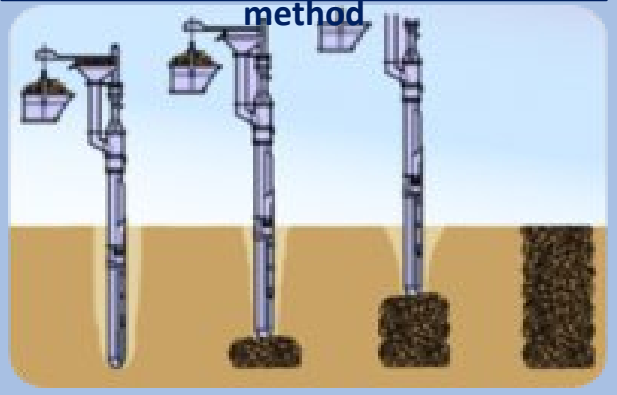
wet top feed installation method



In this method, the Vibro-Probe is hung from a crane and penetrates to the treatment depth under its own weight, vibratory force and water jetting.



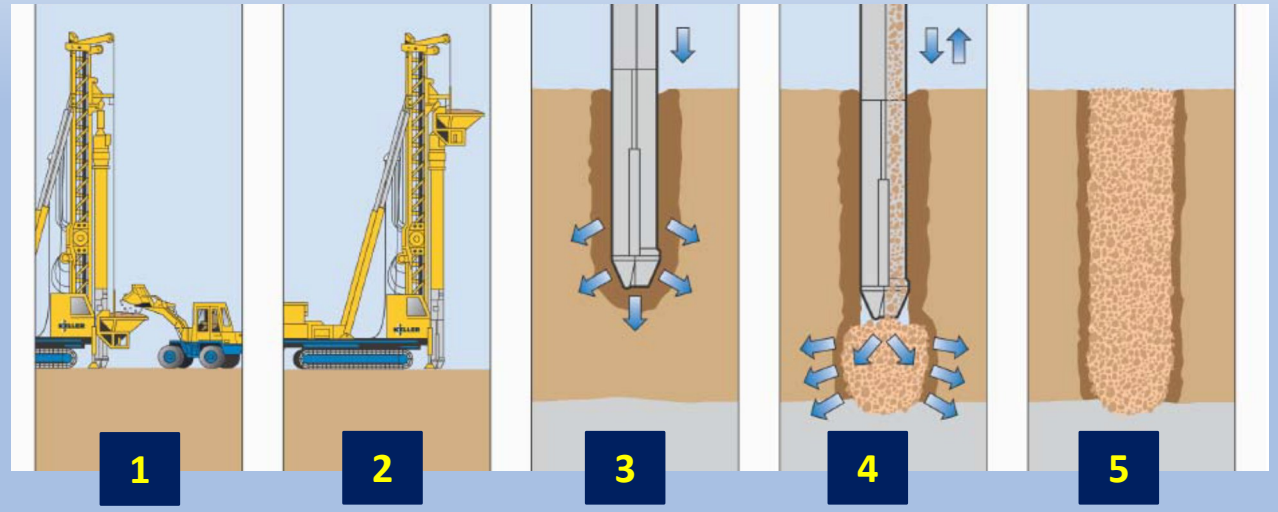
dry bottom feed installation method



In this method, a specialty built stone feed tube system delivers the rock backfill to the tip of the Vibro-Probe under compressed air.

A GENERAL OVERVIEW OF VIBRO-REPLACEMENT TECHNIQUES

Construction Sequence – Bottom Feed Process



1 With the vibrocat stabilised on hydraulic outriggers, the leaders are elevated to the vertical and the vibrator located on the ground at the stone column position. The skip is charged with stone

2 The skip travels up the leaders and automatically discharges stone into the reception chamber at the top of the vibrator

3 The vibrator penetrates the weak soils to the design depth under the action of the vibrations, compressed air and pull down winch facility

4 At the required depth, stone is released and compacted by small upward and downward movements of the vibrator, the pull-down being employed on the downward compacting action

5 With stone being added to the system as necessary at any stage of the construction procedure, a stone column of very high integruity, tightly interlocked with the sorrounding soil, is built up to ground level

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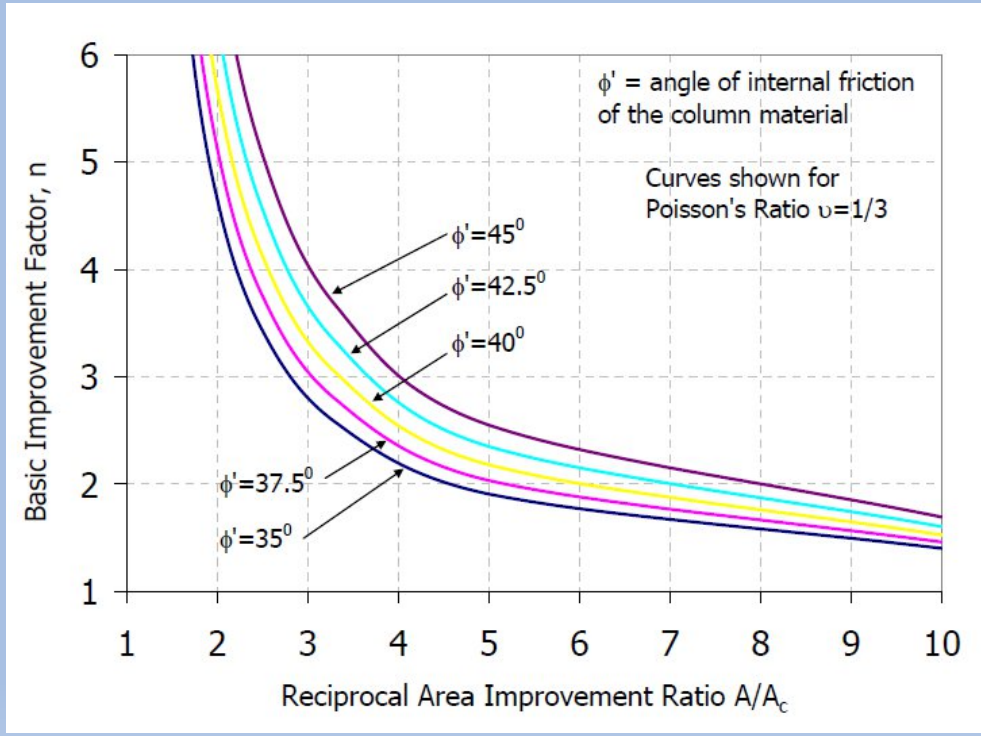
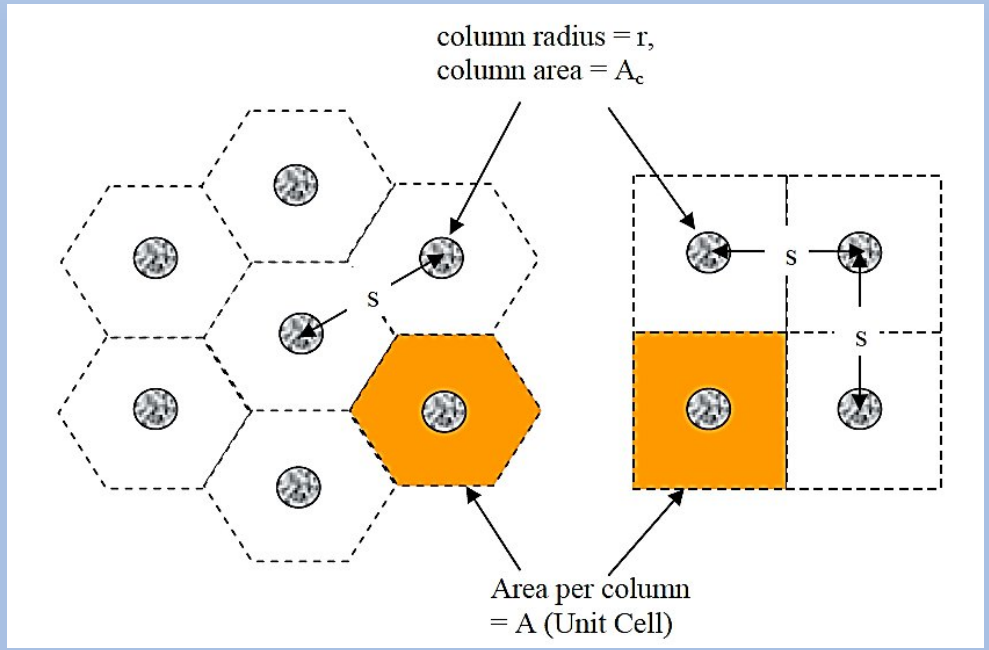
DESIGNING VIBRO-STONE COLUMNS

Absolute and differential settlement restrictions usually govern the length and spacing of columns, and the preferred method of estimating post-treatment settlement in European practice was developed by Priebe (1995) based upon CCET

Priebe's basic improvement factor

$$n = \frac{settlement\ without\ treatment}{settlement\ with\ treatment} = \frac{s}{si}$$





Reciprocal Area Improvement Ratio (RAIR)

$$\frac{A_c}{A} = k\left(\frac{r}{s}\right)^2$$

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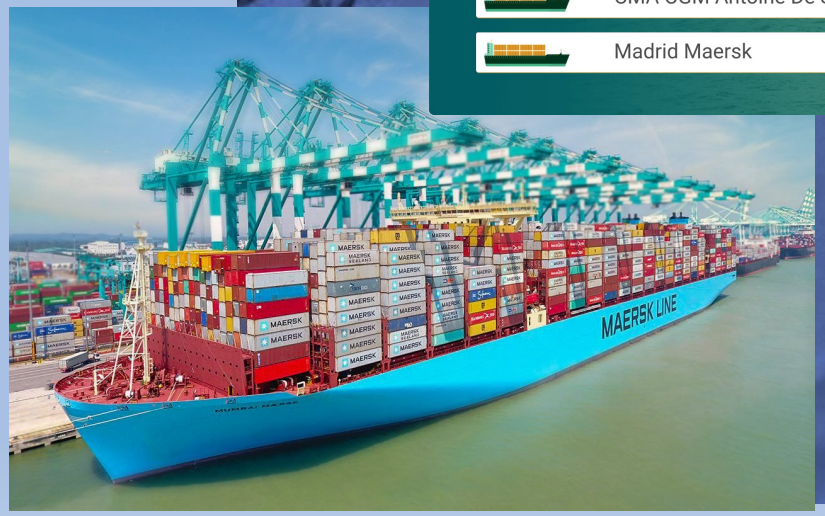
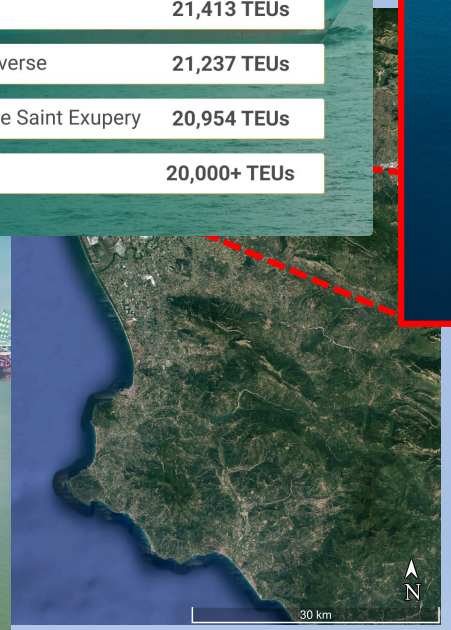
Largest mega container ships in 2022

Ever Ace	23,992 TEUs
HMM Algeciras	23,964 TEUs
HMM Oslo	23,792 TEUs
MSC Gulsun	23,756 TEUs
MSC Mina	23,656 TEUs
CMA CGM Jacques Saadé	23,000 TEUs
OOCL Hong Kong	21,413 TEUs
COSCO Shipping Universe	21,237 TEUs
CMA CGM Antoine De Saint Exupery	20,954 TEUs
Madrid Maersk	20,000+ TEUs





FUNCTIONAL TECHNICAL ADAPTATION OF THE PORT

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Cerema CLIMAT & TERRITOIRES DE DEMAIN

PIANC A.D.1885 AIPCN NAVIGARE NECESSE

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FUNCTIONAL TECHNICAL ADAPTATION OF THE PORT

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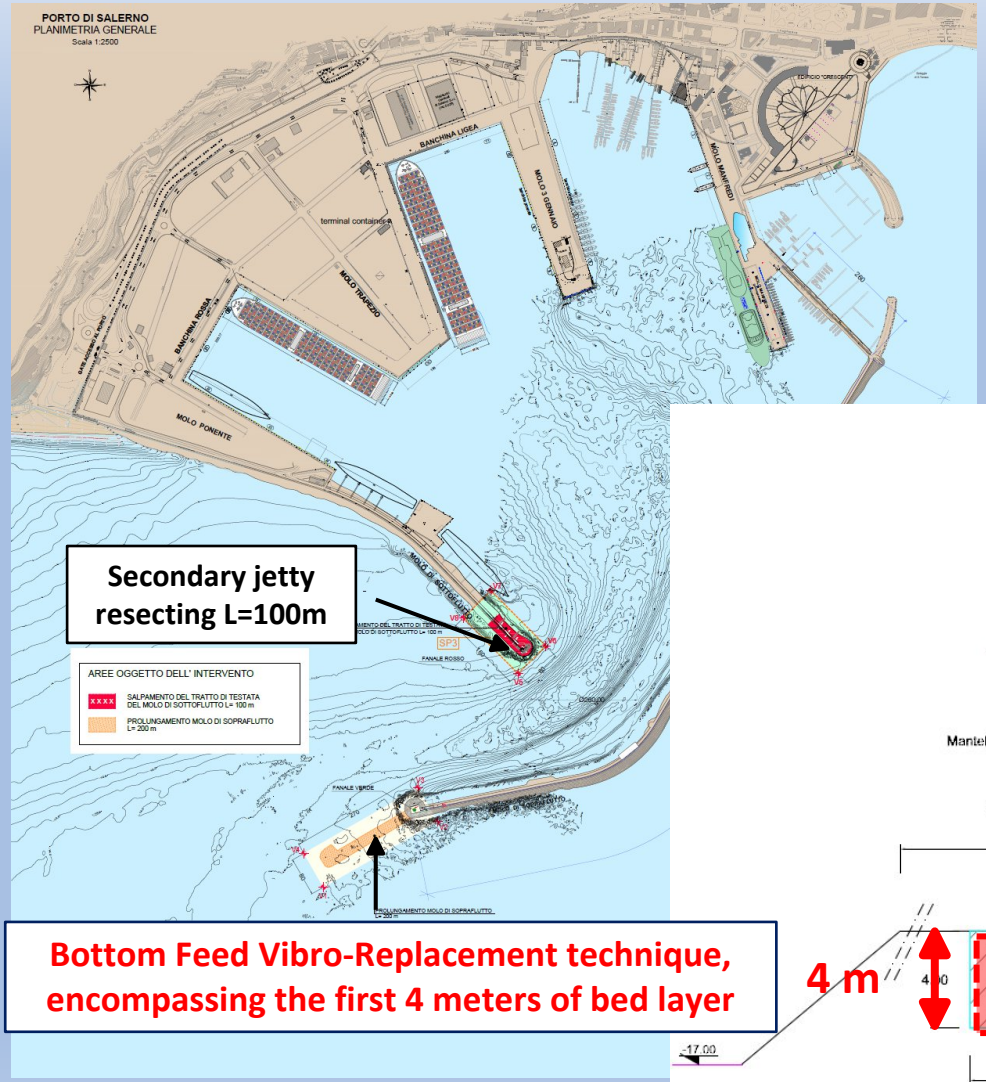
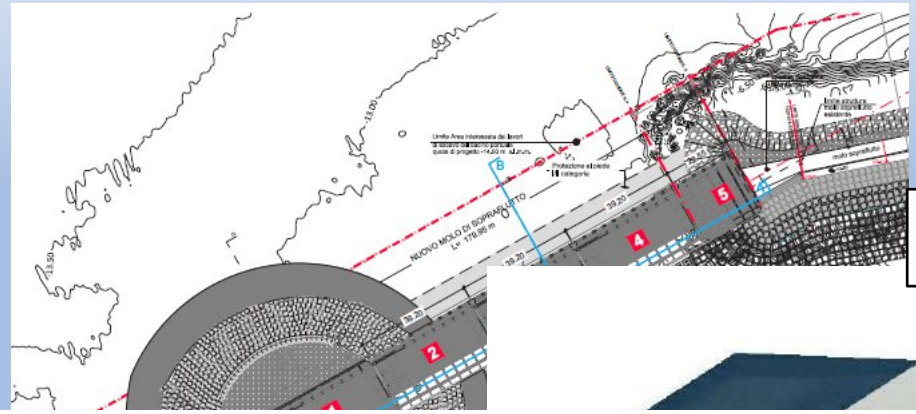
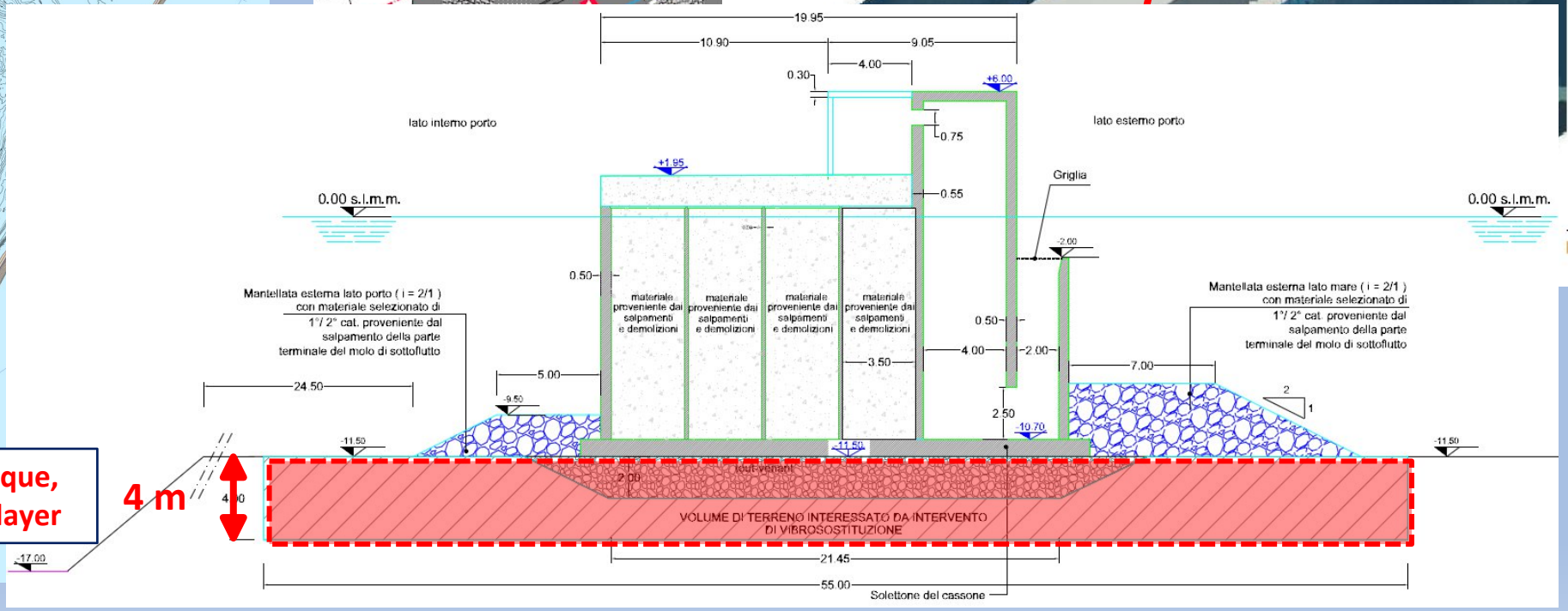
SALERNO PORT ADAPTATION PROJECT



Secondary jetty resecting L=100m



REWEC3®-type caissons (Boccotti, 2012)



Bottom Feed Vibro-Replacement technique, encompassing the first 4 meters of bed layer

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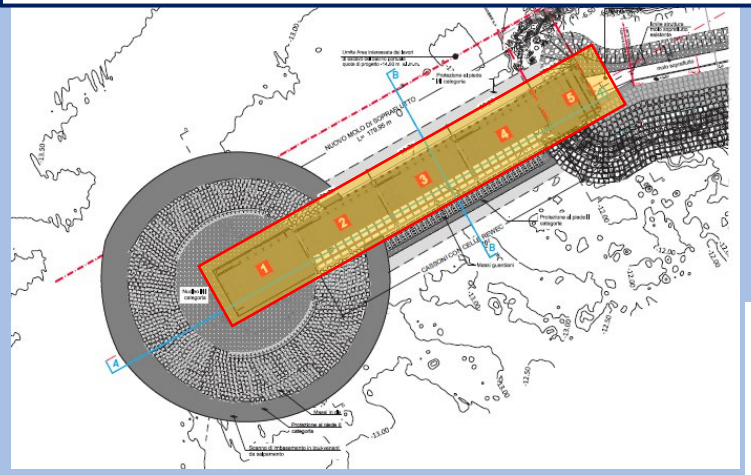
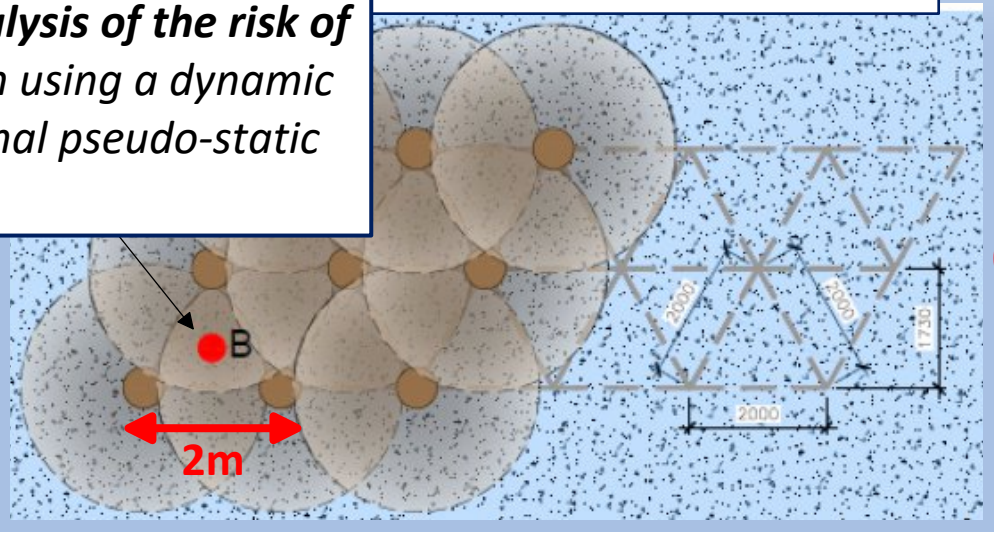
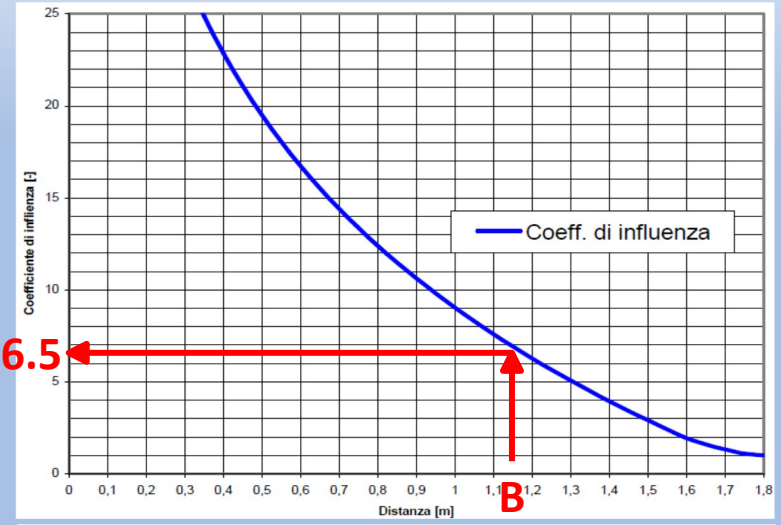
PROJECT UPGRADES

CTA suggestions:
*"perform a thorough **probabilistic analysis of the risk of collapse** of the breakwater-foundation using a dynamic approach in addition to the conventional pseudo-static stability verification"*

stone columns injected using a pontoon-mounted
ng the FEM optimized positioning
ular mesh with a side length of 2 m

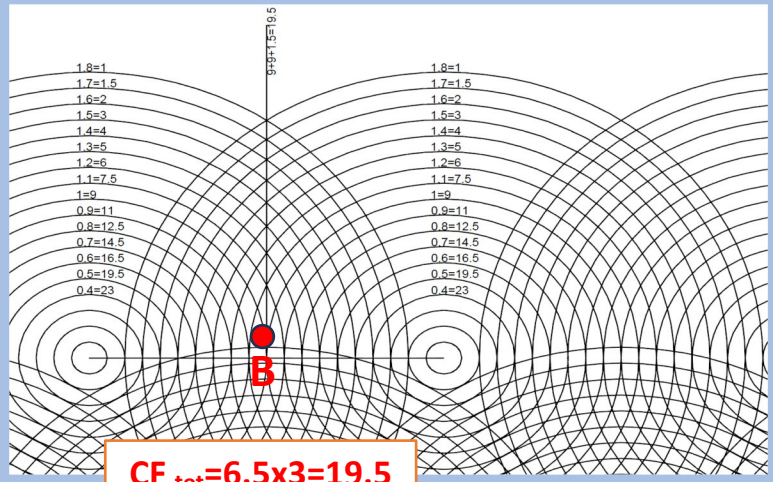






Pre-treatment
N_{spt}=21
N'_{spt}=18
Angle of friction = 31°
Young's modulus= 14.12 Mpa
Relative density = 98%

Post-treatment
N_{spt}=56
N'_{spt}=35
Angle of friction = 38°
Young's modulus= 27.65 Mpa
Relative density = 137%

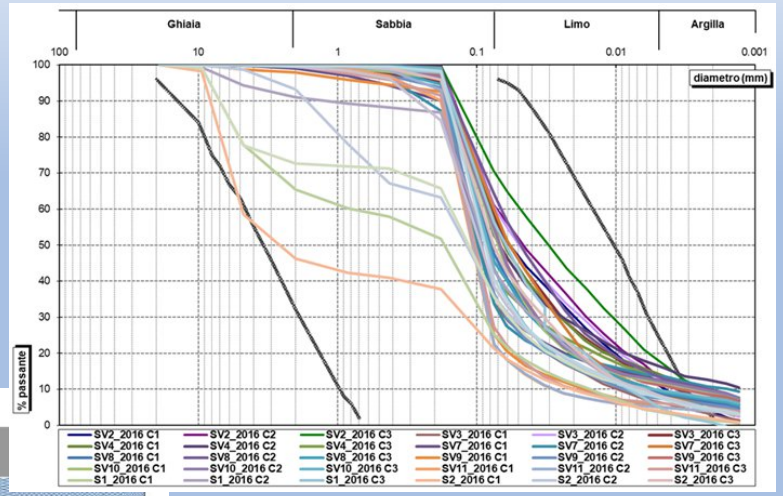


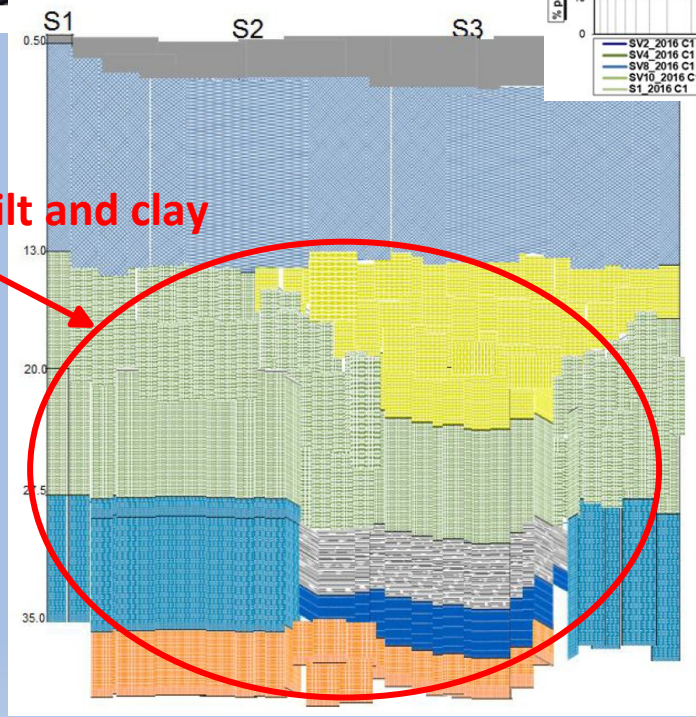
Expected increase in the geotechnical parameters of the soil, resulting in a reduction of absolute settlements and a homogenization of differential settlements among the various caissons.

CF_{tot}=6.5x3=19.5

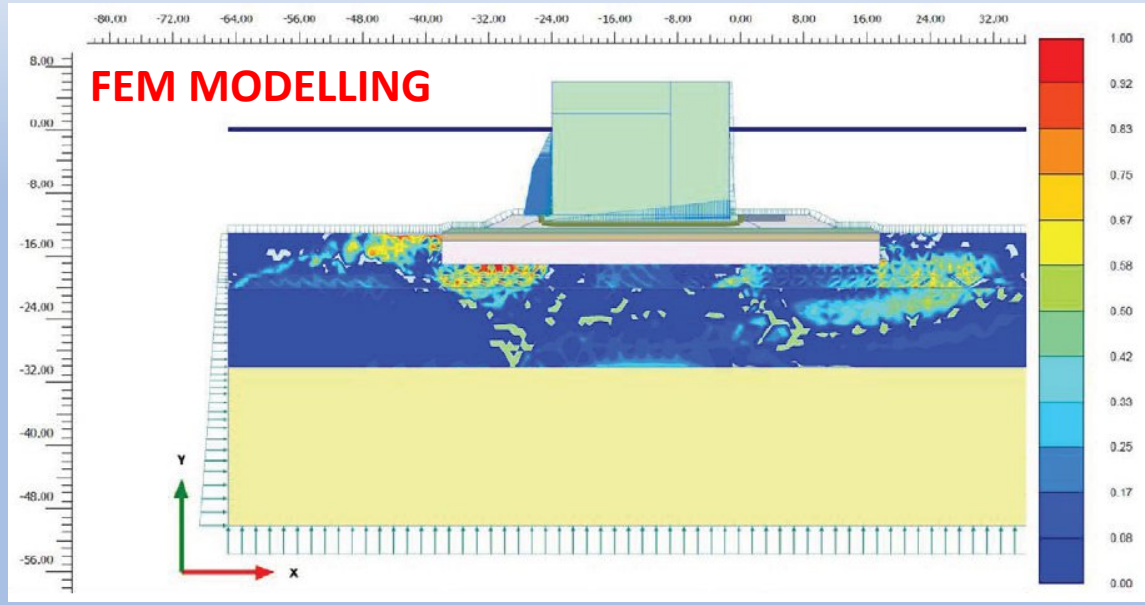
$D_{rf} = D_{r0} + 2\ CF$

SALERNO PORT ADAPTATION PROJECT





FEM MODELLING



Mathematical model (Plaxis)

Geotechnical model of the seabed

Layer	Soil	Layer top (s.l.m.m.)	Layer bottom (s.l.m.m.)	Layer thickness	Unit volume weight γ	Friction angle ϕ	Relative density Dr	Effective cohesion c′	Young Modulus E
		(m)	(m)	(m)	(kN/m^3)	(°)	(%)	(kPa)	(MPa)
I	Sand	-12.5	-20.0	7.5	19	30÷32	33	0÷5	10÷20
II	Sand	-20.0	-30.0	10.0	19	32÷37	41	0÷5	20÷30
III	Silt	-30.0	---	---	17	22	---	50	6

investigate the cyclic movement of the foundation soils (reinforced with the replacement technique) resulting from **earthquake** and **wave actions** (each considered separately).

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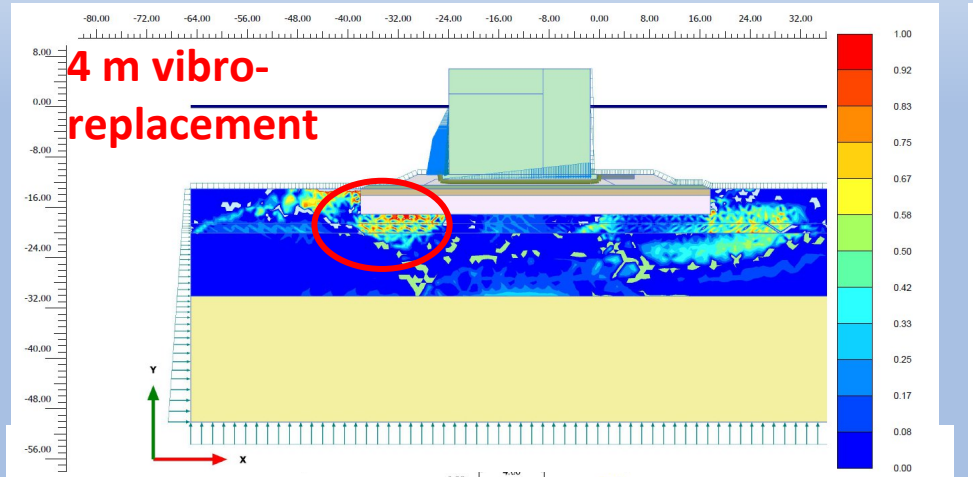
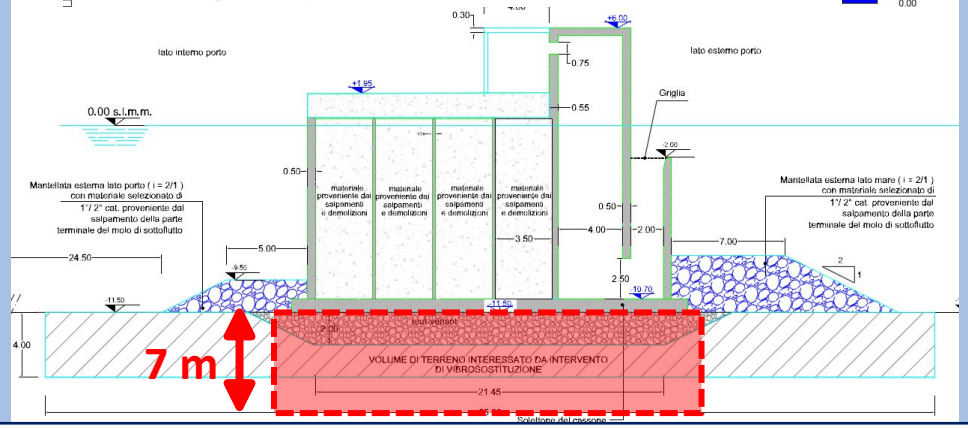
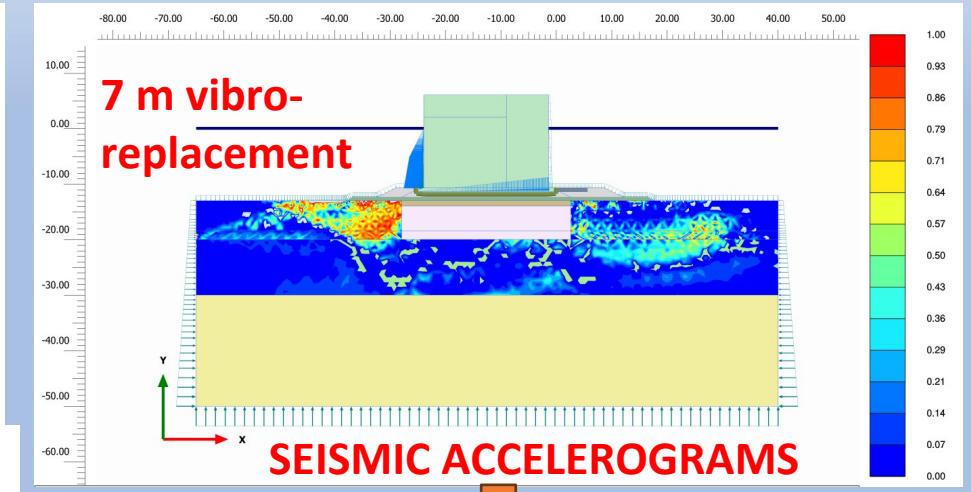
PROJECT UPGRADES

WAVE ACTION

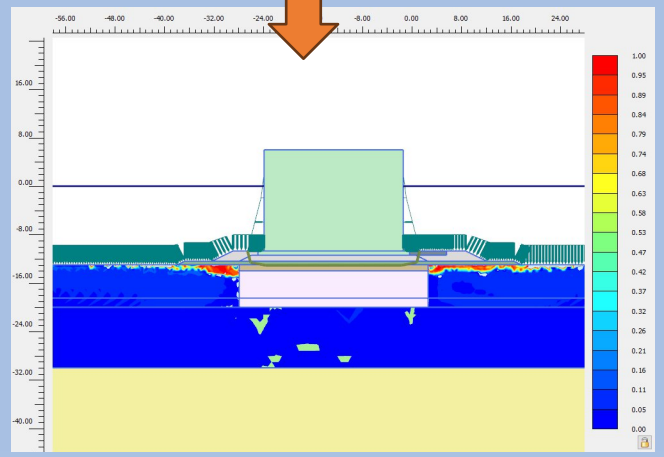


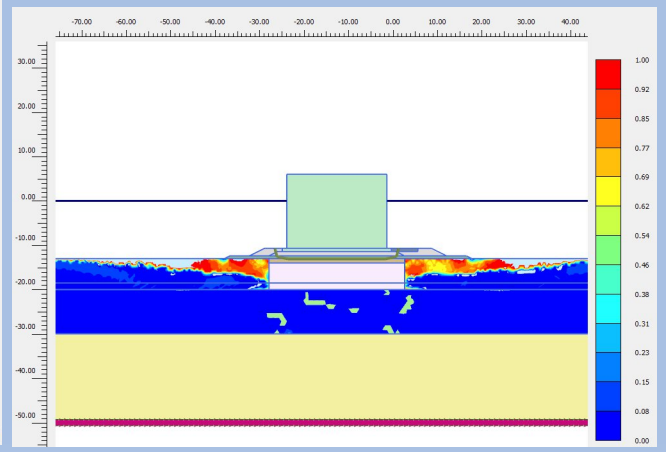


WAVE ACTION



SEISMIC ACCELEROGRAMS

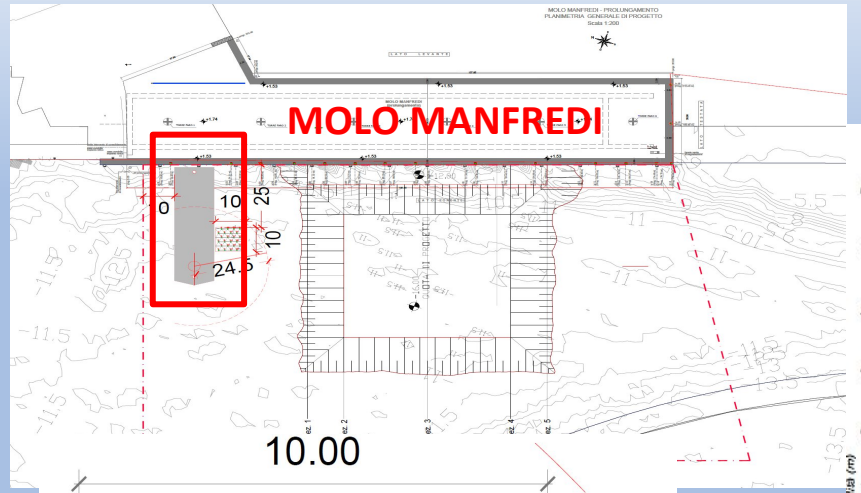


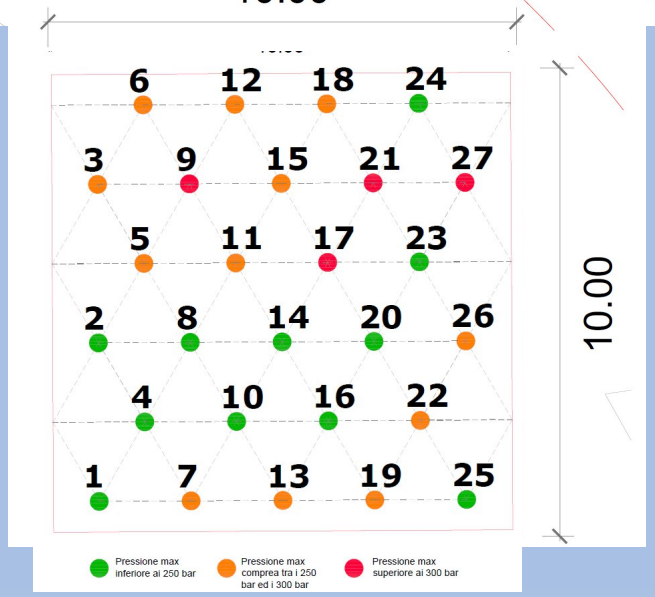


the zone affected by the cyclic mobility phenomenon lies outside the influence area of the concrete caisson's pressure bulb

To prevent the onset of **liquefaction beneath the treated area**, it was preferred to deepen the intervention to a depth of 7 meters, reducing its width to only the area relevant to the reinforced concrete caisson.

TEST FIELD

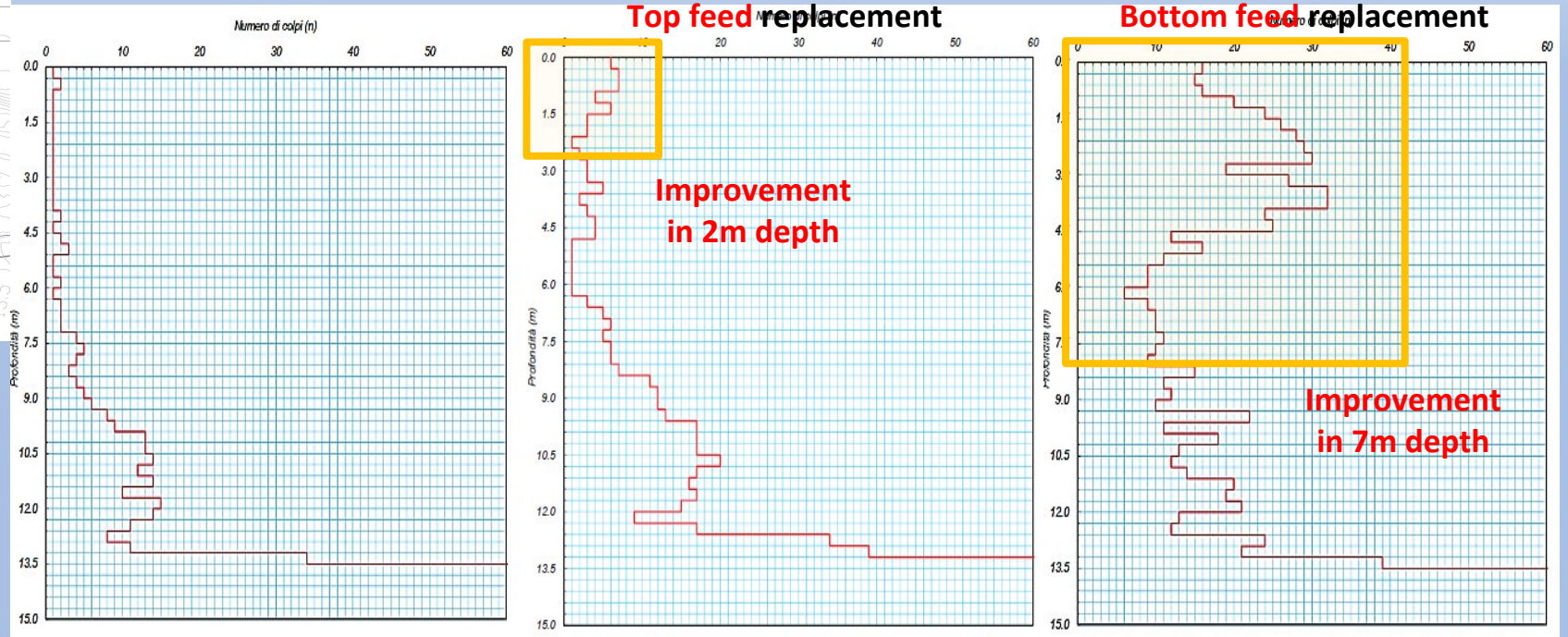


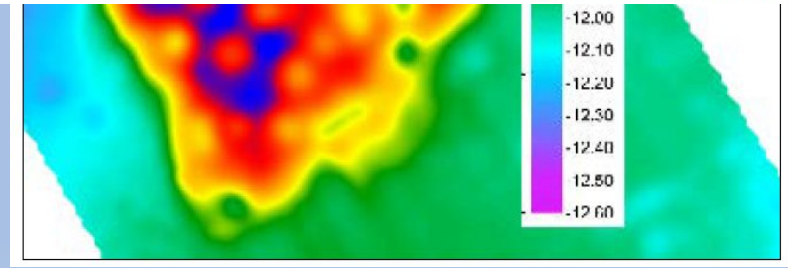


Pre-treatment measurement

Post-treatment measurement
Top feed replacement

Post-treatment measurement
Bottom feed replacement





Multibeam Survey

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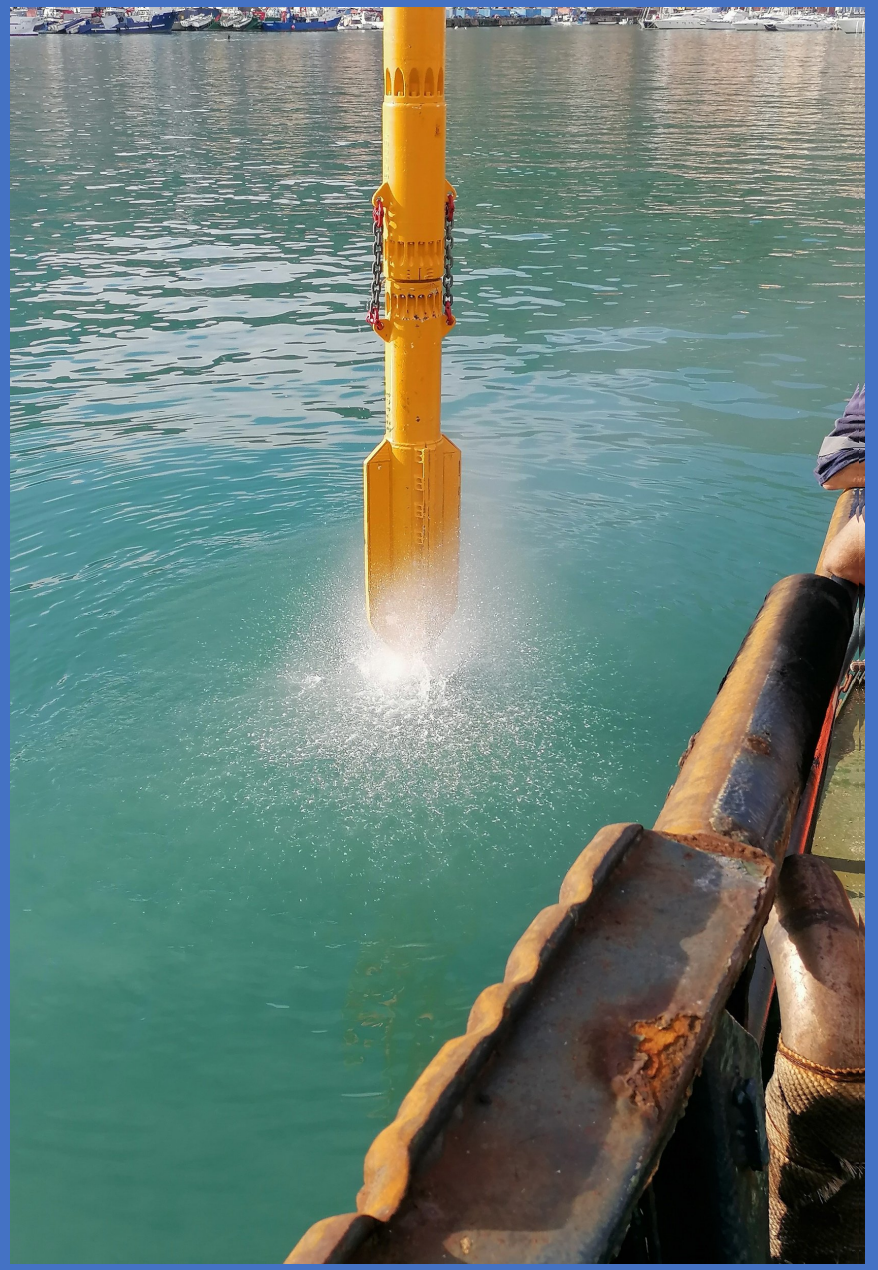

TEST FIELD VIBRO-REPLACEMENT AT THE SALERNO PORT

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