

# Compaction grouting

## CONDAMINE BREAKWATER MONACO



### Consolidation of foundation soil under caisson

**A**s part of the project to expand Condamine harbour in Monaco, Soletanche SAM performed the foundation consolidation work under the abutment caisson.

The compaction grouting was designed to improve the bearing capacity of the foundation and control long term settlement under the static and dynamic loads applied by the superstructure. Compaction grouting consists of injecting a firm but pumpable mortar mix into the ground at high pressure.

After removing the mud and placing a 40/180 stone fill, the caisson was placed on the fill at -30m bsl, providing a working platform at +1m asl.

#### Geology

The stratigraphic cross section is as follows:

- Vibrocompacted fill (stone) from -30 to -40m bsl approx.
- Soft sandy clay (not removed) and moderately hard tufa from -40 to -45m bsl.
- Alternating calcareous sand and clayey silt from -45 to -60m bsl.



View of jobsite

OWNER:	PUBLIC WORKS DEPT, MONACO
ENGINEER:	DORIS ENGINEERING / SIMECSOL
TECHNICAL SUPERVISOR:	VERITAS
MAIN CONTRACTOR:	SOLETANCHE SAM
PERIOD:	JULY TO OCTOBER 2001

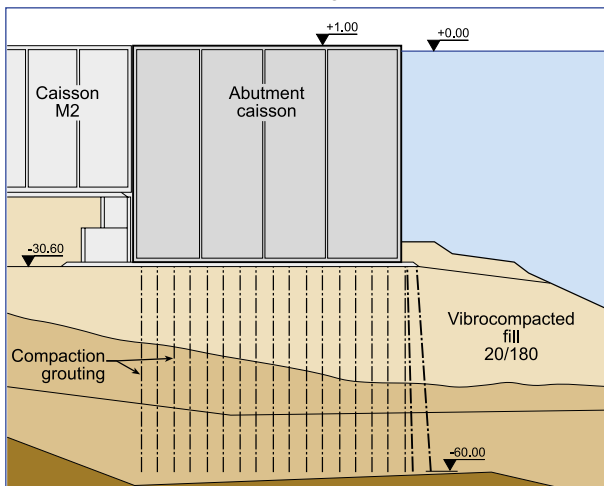
#### MAIN WORKS QUANTITIES:

- Area treated ..... : 3,200 m<sup>2</sup>
- Volume treated ..... : 80,700 m<sup>3</sup>
- Number of grouting holes ..... : 328
- Drilling footage ..... : 7,260m
- Mortar injected ..... : 1,250 m<sup>3</sup>

## Soil improvement

The treatment concerned an area measuring 80 x 40m and a thickness of 25 - 30m of ground under the caisson. The ground was investigated by drilling, coring and pressuremeter testing. The grouting holes were drilled in a 3.40m square array for the primaries and secondaries and a 2.40m square array for the tertiaries where the in place material had not been removed.

The mortar mix was crushed sand, 0/2.5 calcareous filler, 200kg Gardanne fly ash, and 100kg sea-water cement. The ready-mix cement was delivered by mixer truck at 8-10cm slump. After mixing, the



Typical cross section

mortar was kept agitated in the hopper. Mortar 28-day strength was 7 MPa.

Grouting proceeded in one-metre stages from the bottom up. Grouting was stopped after injecting the stage with 200-500 litres at a pressure of 3-5 MPa. Actual figures varied according to the geological formation being treated. These volume and pressure criteria were in fact continually re-adjusted during the work with reference to final pressures and grout take.

The 328 grouting holes represented an aggregate footage of 7,260m (181



primaries, 102 secondaries, 45 tertiaries). A volume of 1,250 m<sup>3</sup> of mortar was injected, an average per cent grout take of 1.55%, made up as follows:

- 1.40% in the fill,
- 5.9% in the material left in place,
- 1.10% in the lower formations.

### Progress of work

The work took place from early July to mid-October 2001 with an average 30 persons

on shift work from 6 a.m. to 10 p.m. and a substantial amount of plant and equipment: crane with 40-metre jib, five DCH 114 and 218 hydraulic drilling rigs, four KOS 1053 grout pumps and three mortar hoppers.

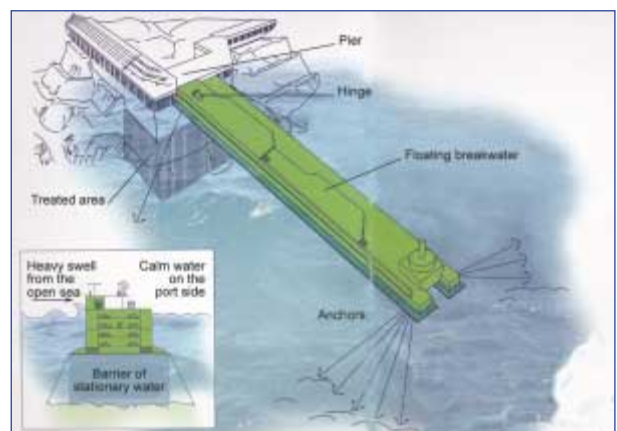
The sequence of work was:

- demolish concrete plug in caisson floor with down-the-hole hammer,
- drill grout holes (with simultaneous casing & rod driving) using a percussion-rotary machine and real-time drilling parameter recording system.

- pull the drill rods string,
- inject mortar from bottom up by withdrawing the casing in 1m stages while recording grouting data. The whole process is controlled from the drilling rig.

During the work, monitoring was conducted by means of settlement gauges cemented into the ground, siting surveys on the caisson, and tests on the mechanical and rheological properties of the mortar.

Post-treatment borehole pressuremeter, cross hole and static penetrometer tests confirmed the success of the treatment, as evidenced by improved mean pressuremeter modules.



Floating breakwater and abutment pier