As 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.

**Main works quantities:**
- Area treated: 3,200 m²
- Volume treated: 80,700 m³
- Number of grouting holes: 328
- Drilling footage: 7,260m
- Mortar injected: 1,250 m³
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 terciaries 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 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 terciaries). A volume of 1,250 m³ 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.

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 penetration tests confirmed the success of the treatment, as evidenced by improved mean pressuremeter modules.