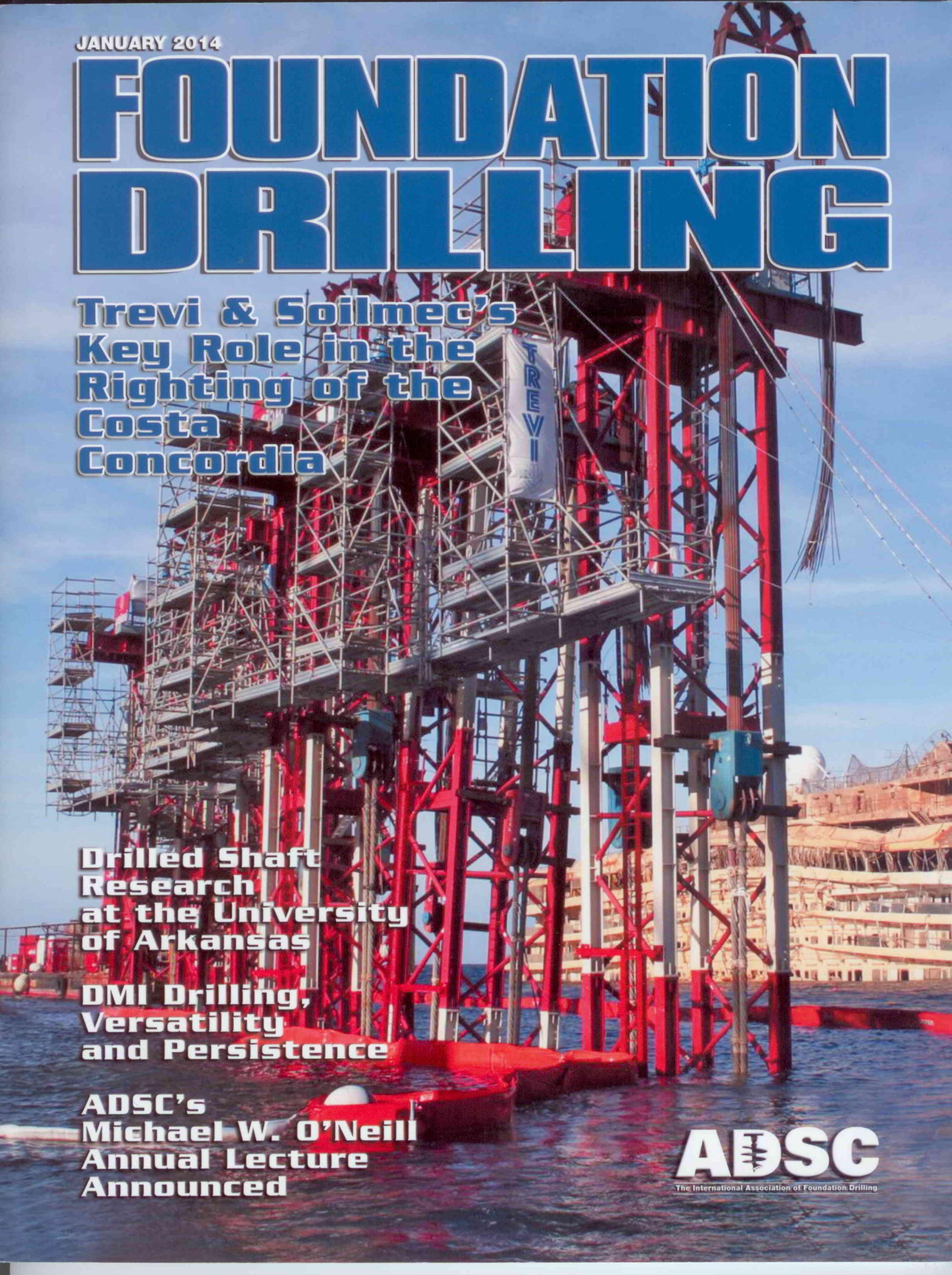
JANUARY 2014

FOUNDATION DRILLING



Trevi & Soilmec's Key Role in the Righting of the Costa Concordia

Drilled Shaft Research at the University of Arkansas

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Cover Feature

TREVI and SOILMEC
Righting the Costa Concordia
Isola del Giglio, Tuscany, Italy

By Tiberio Minotti, Trevi and Vincent Jue, Soilmec North America

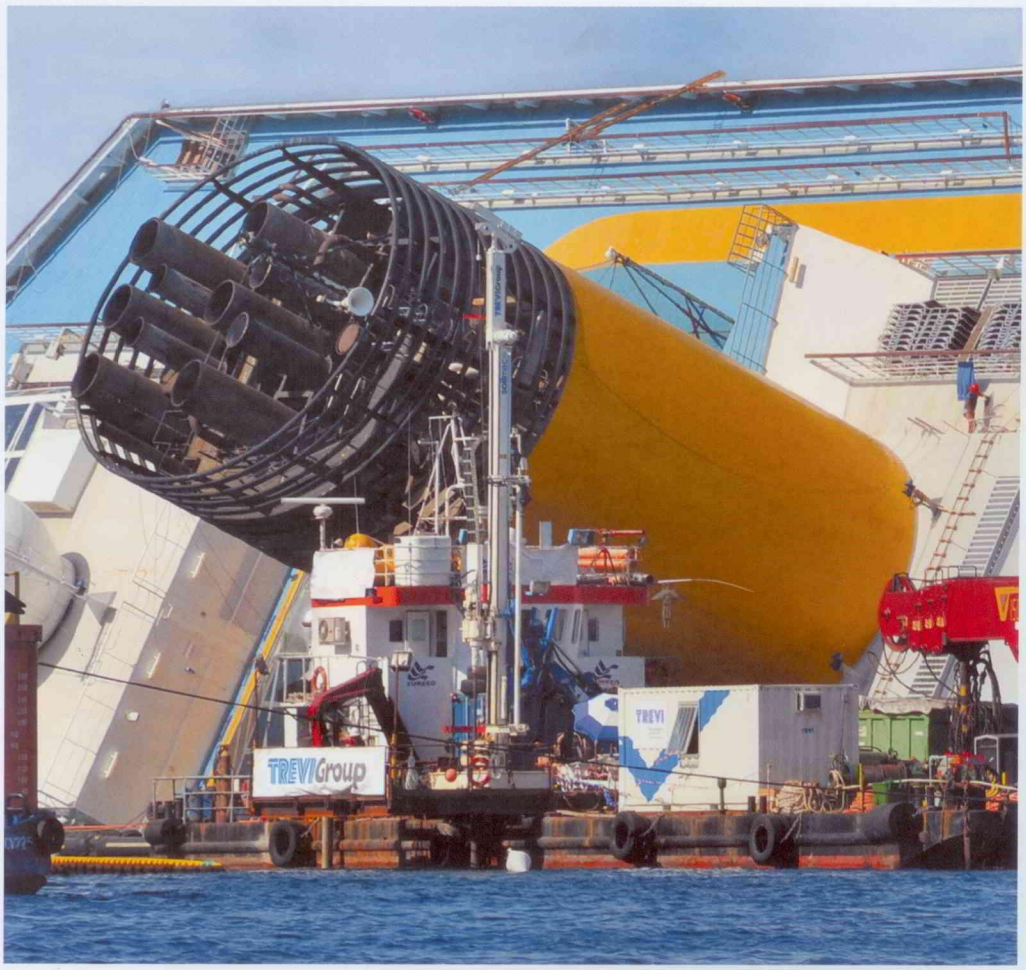
Introduction

The following article comes to *Foundation Drilling* magazine from Tiberio Minotti, of ADSC International Contractor Member, Trevi, and ADSC Associate Member, Vince Jue, Champion Equipment Sales LLC and Soilmec North America. Before launching into the details of the geo-construction aspect of the *Righting of the Concordia* we felt it would be helpful to provide a bit of information about this

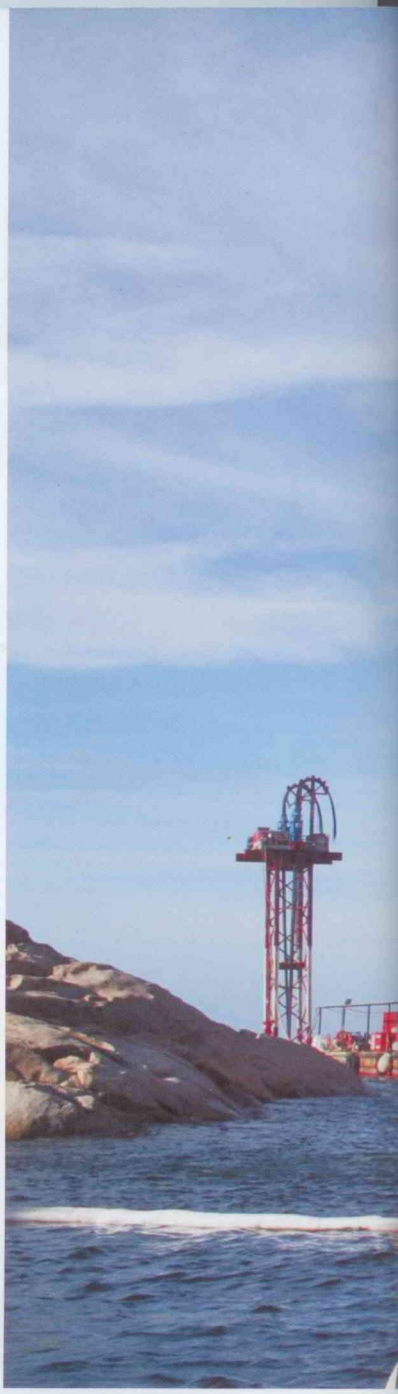
The 950 ft long vessel with a displacement of 50,000 tons struck a reef while deviating from its planned course in the Mediterranean Sea off the coast of Isola del Giglio, Tuscany, Italy.

front page nautical disaster, the grounding of the Italian cruise ship the Costa Concordia on January 13, 2012.

The ship, carrying people from all over the world, was on the first leg of a cruise around the Mediterranean Sea, starting from Civitavecchia in Lazio, Italy. The



RCT worked off a barge-mounted Soilmec SM-20 drilling rig placed along side the ship's hull.



950 ft long vessel with a displacement of 50,000 tons struck a reef while deviating from its planned course in the Mediterranean Sea off the coast of Isola del Giglio, Tuscany, Italy. The collision with the reef could be heard onboard and caused a temporary power blackout when water flooded the engine room. The captain, having lost control of the ship, did nothing to contact the nearby harbour for help but tried to resume the original course it was on prior to the U-turn back to Giglio.

In the end, the Captain had to order an evacuation when the ship

One of the World's Most Tricky and Complex Engineering Projects

Strandjacks are mounted to the top of turrets that were constructed on the rock anchors. Chains attached to the strandjacks were passed under the hull and fixed to the port side of the wreck for balancing during rotation and parbuckling of the ship.

grounded after an hour of listing and drifting. Meanwhile, the harbour authorities were alerted by worried passengers, and vessels were sent to the rescue. During a six-hour evacuation, most passengers were brought ashore. The search for missing people continued for several months, with all but two being accounted for. There were a total of 4,252 people aboard comprised of passengers and crew. Thirty-two people lost their lives and sixty-four were injured in this totally avoidable debacle which came to pass when Captain Francesco Schettino deviated from the ship's computer programmed route. It has been reported that his apparent intent was to bring the ship close to the island for an unofficial "salute" to the local islanders.

The Costa Concordia is one of the largest ships ever to have been abandoned, supplanting the famous Titanic with 2,223 passengers on board, which on April 14, 1912 struck an iceberg in the North Atlantic Ocean and sunk 375 miles south of Newfoundland Canada, 1,517 people perished. The Titanic was on an ocean voyage from Southampton England to New York City. In the case of the Concordia the 4,252 people who fled its decks, nearly twice as many as were aboard the Titanic, represents the largest maritime evacuation in history. Many felt the ship was doomed from the day of its christening when the champagne bottle failed to break, an ominous portent to superstitious mariners.

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The Concordia disaster, in addition to the devastating event itself, created fears of an ecological disaster, as the partially submerged wreck was in danger of slipping into considerably deeper water with a risk of oil pollution that could have severely compromised the long term future of the popular tourist area. Fortunately this potential disaster was averted by the extraction of all of the fuel oil by March 24, 2012.

The loss of life and the subsequent internationally publicized investigation of the causes are well documented. The ship's captain was arrested and charged with a wide range of misdeeds and crimes including manslaughter, failing to assist 300 passengers and failing to be the last to leave the wreck. In fact he is charged with abandoning incapacitated passengers. If convicted he faces up to 20 years in prison. (S. Scot Litke, Editor)

The magnitude of the ship is obvious in this photo.

The Project: A Solid Foundation

By Tiberio Minottia and Vincent Jue

In one of the world's most tricky and complex engineering projects, crews righted the Costa Concordia cruise liner off the environmentally sensitive Giglio Island, near Tuscany, Italy where it grounded and capsized nearly two years ago. As in other engineering endeavors, a solid foundation was integral to providing structural capacity for the immense loads, in this case, loads involved in the parbuckling operation.

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After hitting the rocky reef on January 13, 2012, the 300 meter long, 114,000 ton cruise ship came to rest on its side. Initial activity focused on removing 2,040 cubic meters of fuel from the ship and 240 cubic meters of sewage, to reduce the risk of environmental damage.

A Soilmec SM-20 microdrilling rig was used for the subsurface investigation into granitic rock.

Meanwhile, Costa Crociere, the ship's owner, and the Costa Concordia Emergency Commissioner's Office weighed alternatives for salvaging the vessel, ultimately selecting the Titan-Micoperi Consortium in April 2012. The Titan-Micoperi Consortium is a partnership of Crowley Group's Titan Salvage, a marine salvage and wreck removal company based in Pompano Beach, Florida, and marine contractor Micoperi of Italy.

Titan-Micoperi's six-phase plan called for safeguarding the marine environment, preserving the island's tourism and wider economy, while removing the ship intact and towing it to a salvage yard. The first part of that plan focused on learning more about the geological conformation of the site and securing the vessel to prevent it from slipping deeper into the water. That's when ADSC Contractor Member, Trevi, a foundation engineering and construction company based in Cesena, Italy, was brought in for their expertise.

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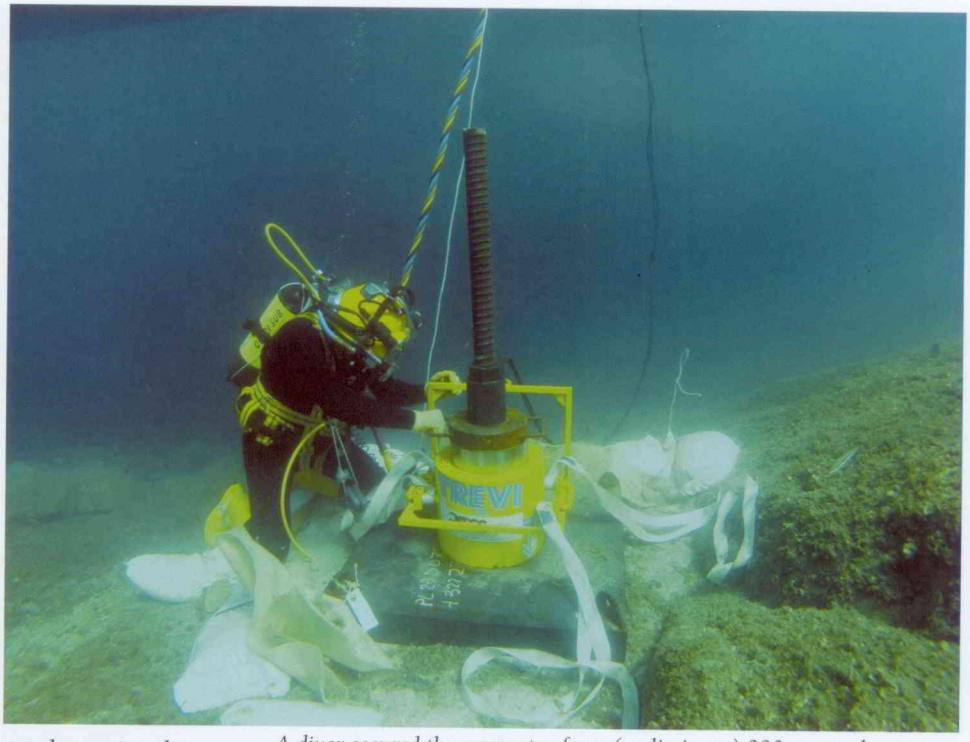

A diver secured the apparatus for a (preliminary) 290-ton anchor test.

Soil and Rock Testing

Trevi's RCT Srl division performed soil and rock testing to provide designers and other participants with a greater understanding of the geologic conditions. RCT carried out this work using a barge-mounted Soilmec SM-20 drilling rig, with a weight of about 20 metric tons, placed along side the ship's hull. To optimize drilling in challenging weather and sea conditions, Soilmec developed a floating drill system installed below the rotary head. The floating drill head cushioned wave-related forces that could have compromised the quality of the coring.

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All work was conducted from barges directly off the shoreline.

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An aerial view of the recovery site.

Trevi conducted subsurface investigations along the perimeter of the wreck using simple corers and double core barrels to recover continuous sample cores. Crews conducted pressure meter tests to determine in-place strength parameters and performed video inspection to identify discontinuities within the rock.

The rocky seabed, with a slope of about 20 percent to 30 percent, subjected the long drilling set rods and casings to high bending stress. The survey exposed predominantly compact granite with loose-sand filled fractures that presented challenges during construction.

The successful results obtained allowed Trevi to identify the basic parameters for the design, construction, and installation of geotechnical structures suitable for the parbuckling phase.

Installing Hold-Back Anchor Foundations

The next major activity involved constructing a hold-back system for ship stabilization. Limited work space between the wreck and the shore precluded the use of large-diameter foundation piers. Therefore, four underwater trapezoidal-shaped metal anchor blocks, weighing about 30 tons each, were placed on the seabed. Each anchor block was secured to the seabed with 10 pre-stressed micropiles with 63.5 mm tendons grouted into 12 to 16 meter deep holes.

Drilling was complicated by high tolerances for hole verticality through the inclined granite surface, discontinuities within the rock, and the effects of wave action.

Trevi crews worked off a barge-mounted Soilmec SM-21 drilling rig to drill the required 203 mm holes to depths into the granite. The Soilmec drilling rig features a modular design, perfect for installing anchors and other work. Proportional, hydraulic servo-assisted controls enable easy, precise and smooth drilling and positioning operations. The SM-21 was outfitted with a floating system beneath the drill head, this innovation by Soilmec reduced stand-by time and improved the quality of coring by protecting against the adverse effects of wave action.

Wassara down-hole-hammer drills, using water-powered percussive drilling technique, were chosen because they require no oil lubrication, reducing the risk of a spill in the sensitive waters. Project specifications did not permit high-pressure compressed air drilling.

As Trevi brought drill cuttings to the surface, crews on the barge managed and treated the cuttings using flocculants and a coagulant to separate solid particles from seawater. Working around the clock, Trevi installed three anchor bars per day. Drilling was complicated by high tolerances for hole verticality through the inclined granite surface, discontinuities within the rock, and the effects of wave action. To ensure proper installation of the anchor bars, the technical specifications limited the anchor holes to a maximum deviation of 0.5% from vertical. Before parbuckling, crews tested the anchor bolts by applying a load of 800 tons. They held. Tension during parbuckling was only 150 tons. Load and displace-

ment monitoring revealed no movement of the anchor blocks during loading.

Titan-Micoperi divers attached two large steel cables to each of the anchor blocks, threaded them under the ship's hull and attached them to hydraulic jacks positioned on the outboard side of the ship for stabilization, finishing this portion of the project in November 2012. Next, Titan-Micorperi constructed seven additional anchor blocks to support cable towers and jacks for the subsequent parbuckling operation. Trevi's portion of the project wrapped up in July 2013.

After the Costa Concordia is righted the devestation is clear and it is amazing that more lives were not lost.

Completing the Salvage

Mindful of the project's critical timing, getting the ship off the shore before winter, Trevi teams completed the work with no downtime, working 24 hours a day, seven days a week.

The next step of Titan-Micoperi's plan consisted of providing a stable base on which to support the uprighted ship by creating an artificial seabed consisting of concrete-filled grout bags between the shore and a pier-supported steel platform. Crews then attached 15 sponsons (pontoons) to the exposed port side of the ship to provide the vessel with flotation.

Mindful of the project's critical timing, getting the ship off the shore before winter, Trevi teams completed the work with no downtime, working 24 hours a day, seven days a week.

On September 17, 2013 as the world watched, the parbuckling went smoothly. The team used strand jacks, with a pulling force of 6,000 tons, to rotate the vessel 65 degrees to rest on the grout-bag seabed and platform.

Next, crews will attach 15 refloating sponsons to the starboard side of the vessel. Once refloated, Titan-Micoperi will tow the Costa Concordia to a shipyard, where it will be dismantled, to be cut up for scrap.

The sheer size of the cruise liner, limited work space, challenging geologic conditions, and the risks related to its removal made the salvage the most complex ever attempted.

The sheer size of the cruise liner, limited work space, challenging geologic conditions, and the risks related to its removal made the salvage the most complex ever attempted. The 600 million euro ($800 million USD) project has required the talents of more than 500 engineers, divers, welders, technicians and other skilled craftsman from 26 countries. They worked around the clock, only pausing for bad sea weather conditions.

This event and the resulting reclamation will certainly go down in history.

About the Authors

Tiberio Minotti was Trevi's project manager for the Costa Concordia project. Vincent Jue is a Vice President with Soilmec North America. Soilmec manufactures drilling and ground engineering construction equipment. Vincent can be reached at vjue@champion-equipment.com.

Project Team

Owner:	Costa Crociere
General Contractor:	Titan-Micoperi Consortium: Titan Salvage and Micoperi
Specialty Geotechnical Contractor:	Trevi*

**Indicates ADSC Member*

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