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DEEP FOUNDATIONS

Second Avenue Subway: An OPA Contender

Micropile Crane Support

Panama Canal

Ground Improvement Specifications

Construction of foundation piles for the new Pacific Access Channel

Expanding the Panama Canal – a Wider Path Between the Seas

The expansion of the Panama Canal is one of the 25 biggest and boldest projects on the planet this decade, according to an article by Tim Newcomb in *Popular Mechanics*. At the cost of $5.25 billion, the project will create a new lane of traffic along the canal through the construction of an additional set of locks, doubling the waterways' transport capacity. These new locks will enable the canal to handle larger ships.

The Panama Canal serves more than 144 maritime routes connecting 160 countries. About 14,000 ships sail through the canal every year. Lock chambers raise and lower ships between different waterway levels. One lock system lifts ships from the Pacific up to the level of Gatun Lake, and another lock system lowers them at the Atlantic side. The water used to raise and lower the vessels in each set of locks comes from Gatun Lake by gravity through a system of culverts.

The Panama Canal expansion project is comprised of four main tasks: constructing two new lock complexes, constructing a new Pacific Access Channel, dredging the waterways and raising the operational level of Gatun Lake. The new 6.1 km (3.8 mi) Pacific Access Channel will provide navigation access from the new Pacific locks to the existing Gaillard Cut, the narrowest stretch of the original Panama Canal. Two dams with a combined length of almost 4 km (2.5 mi) and a height of about 30 m (98.4 ft), referred to as Borinquen Dams 1E and 2E, form the new channel's eastern bank. Two additional dams with a total length of 1.4 km (0.9 mi), known as the Borinquen Dams 1W and 2W, help form the western bank.

Using Soilmec equipment, the Trevi Group branch in Panama (Trevi Cimentaciones y Consolidationes SA, formerly Trevi Galante SA) conducted soil investigations and installed foundation piles, diaphragm walls and injection walls for a wide variety of functions and at various locations along the 80 km (49.7 mi) long Panama Canal that connects the Atlantic Ocean to the Pacific Ocean.

Soil Investigation

The canal is located within a sedimentary basin formed about 3 million years ago, when the Pacific Plate slid slowly under the Caribbean Plate. The entire area is characterized by a complex lithology, from fine grainy materials (sediments, sand and mud) to hard rock with resistance above 50 MPa (500 tsf). The Atlantic area is composed primarily of silt, clay, calcareous sandstone and volcanic tuff, whereas sedimentary and volcanic rocks dominate the Pacific sector.

Soil investigations were performed to identify the subsurface conditions at select locations, drilling exploratory holes with varying depths and analyzing a total of 6,000 linear meters of soil: 3,500 m (11,500 ft) of soil on the Pacific side and 2,500 m (8,200 ft) on the Atlantic side. These soil tests included standard penetration tests (SPT) to determine the soil density, Lugeon tests to verify the permeability of the bedrock and Lefranc tests to measure the permeability of the soil.

Soilmec SM-305, SM-5 and SM-8 multipurpose microdrilling rigs were used to drill and install the necessary instrumentation, including piezometers to monitor groundwater pressure and inclinometers to measure potential slope movement.

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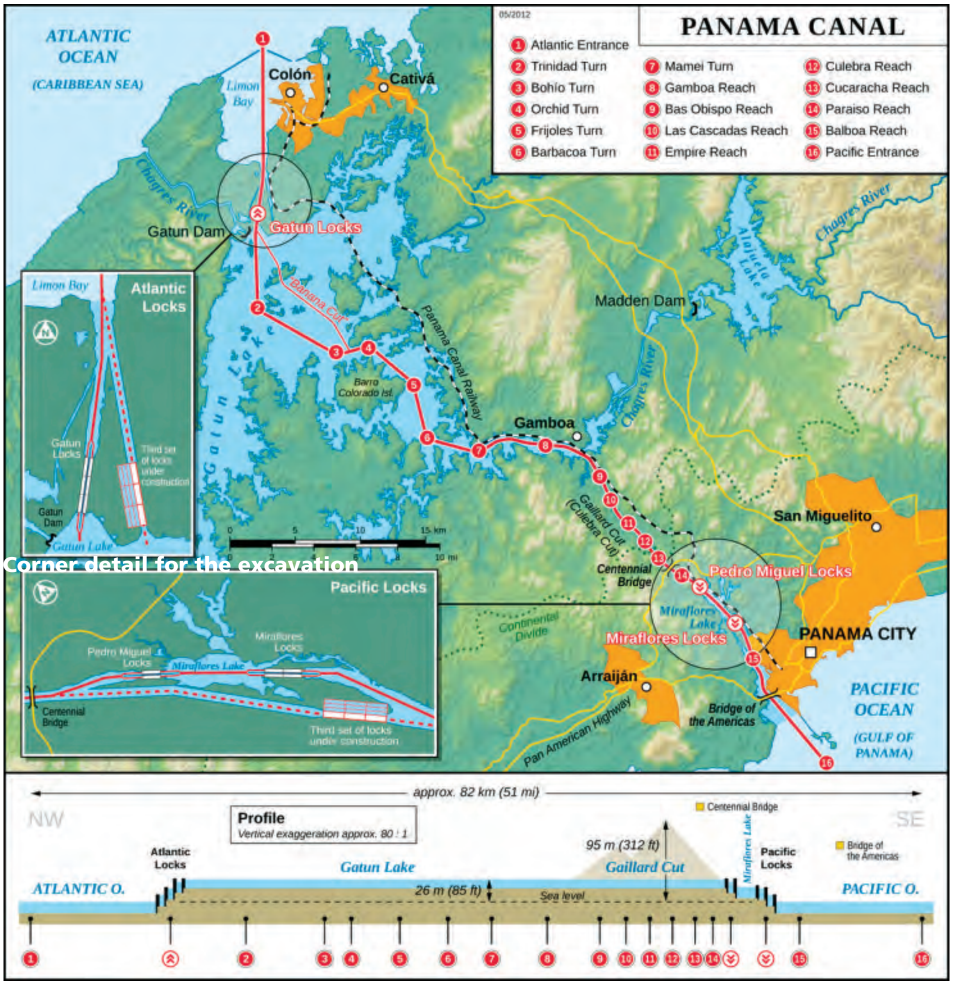

Corner detail for the excavation

Original and new sequence of locks and passages
(Courtesy of Thomas Römer/OpenStreetMap data via Wikimedia Commons)

Soilmec SR-70 and R-930 rigs drill large-diameter bored piles

Foundation Piles

Deep drilled piles were chosen as the preferred foundation type for structures throughout the canal expansion. Trevi Panama constructed over 14,000 linear meters (45,900 ft) of large-diameter bored piles for locks, docks, bridges, dams and more. It used Soilmec SR-60, SR-70, R-825 and R-930 hydraulic drilling rigs for drilled pile installation throughout the project.

Fully-cased, 1,500 mm (59 in) diameter piles were installed on the Atlantic side for the construction of a temporary dock near the Gatun Lake entrance, which was used to unload the new locks shipped from Italy. Fully-cased piles with a 1,500 mm (59 in) diameter were also constructed for the adjacent foundations including: an expanded parking and storage area near the Atlantic locks, the Atlantic gates delivery route between the storage area and locks assembly area, a new four-lane bridge next to Thelma King Road that will connect the city of Colon to the opposing bank, and a new lighthouse in the Atlantic locks area.

On the Pacific side, 1,500 mm (59 in) diameter foundation piles were installed for a temporary dock designed to unload the locks coming from the Atlantic parking and storage area; the installation of these drilled shafts proved difficult due to the hard subsurface containing many cobbles and boulders. Bored piles with a diameter ranging from 800 to 1,500 mm (31.5 to 59 in) were also constructed for the foundations of the main control building and the main cells of the Pacific approach channel inlets and outlets.

Diaphragm Walls

As part of the Panama Canal upgrades, a new Pacific Access Channel was planned to allow ships to bypass Miraflores Lake. This new channel will operate 9 m (29.5 ft) above the existing channel. A new 2.3 km (1.4 mi) long cofferdam, called Borinquen Dam 1E, was needed to separate waters between the new channel and lake. A diaphragm wall was constructed for this dam with a depth of 18 m (59 ft) and thickness of 800 mm (31.5 in). The walls were excavated using a hydraulic clamshell BH-7 grab with bentonite slurry. Once the excavation was completed, the concrete panels were poured using the traditional tremie method. This method was used to install diaphragm cut-off walls throughout the Panama Canal project.

Two new, three-chamber lock complexes were built — one located on the Pacific side southwest of the existing Miraflores Locks and the other located east of the existing Gatun Locks. Each lock chamber has three basins that were designed to use 7% less water than the existing locks and to reuse 60% of the water for each transit. These 18 new, water-saving basins also required concrete cut-off walls to stabilize excavation sections with high-permeability strata. Over 4,000 sq m (43,000 sq ft) of concrete

Foundation piles for the Pacific approach channel inlet

diaphragm walls were installed with up to a 20 m (65.6 ft) penetration depth for these basins. A concrete cut-off wall was also built to a depth of 25 m (82 ft) to serve as a seepage barrier to the main lock system.

Grouting

The Borinquen Dams must retain Gatun Lake and the upstream waterways of the Panama Canal, so their reliability is critical. The design of these dams was challenging due to variable foundation conditions, limited availability of construction materials, a wet tropical climate with a short dry season, the high probability of foundation fault rupture from seismic activity and the potential exposure to ground ships. Given these challenges, the dams were constructed as zoned central core rockfill embankments with a height up to 35 m (114.8 ft). The shells of the dam were built with sound agglomerate and basalt and founded on rock, whereas the dam cores were built with residual soils and founded on rock.

An injection grout curtain was installed to guarantee the waterproof sealing of all rock cracks and discontinuities in the foundation of three of the Borinquen Dams. Specifically, over 35,500 linear meters (116,500 ft) were drilled and 314 tonnes (346 tons) of cement were injected to build the three grout curtains, which were constructed to a depth of approximately 25 m (82 ft) in two rows with injection points spaced 3 m (9.8 ft) apart. These grout injections were made in series using the split-spacing method, with primary and secondary holes of the same row spaced every 6 m (19.7 ft). Tertiary holes were placed in between adjacent primary and secondary holes. In some areas, additional tertiary quaternary and even quintary holes were needed.

The drilling and grouting for these dam foundations were difficult due to the irregularity of the subsurface conditions, uneven working surfaces and hard rock that required cased drilling. Flooded excavation areas also had to be overcome. Grout was injected using Soilmec SM-8 and SM-5 microdrilling rigs and Soilmec GS1 and GI ET8 grout plants.

Under a different contract, 95,000 linear meters (312,000 ft) were drilled and 4,000 tonnes (4,400 tons) of grout were injected to create a 25 m (82 ft) deep waterproof screen for the PAC4 Pacific Access Channel's remaining Borinquen Dam to prevent groundwater seepage and erosion of materials through the dam foundation. For these foundation works, the same method and equipment were used — SM-8 and SM-5 microdrilling rigs and GS1 and GI ET8 injection plants.

Trevi Panama has played a crucial role in the soil investigations and the installation of foundation piles, diaphragm walls and injections for this megaproject. These works were performed from September 2012 through January 2015.

The Panama Canal expansion is almost finished. All dredging activities are complete. The new Atlantic Locks, Pacific Locks and Pacific Access Channel have been constructed and flooded — a major milestone. Commissioning and testing continues, and the expanded canal is expected to be fully functional in April 2016 to give the world a wider path between the seas.

Soilmec SM-8 microdrilling rig drills and injects grout for the Borinquen Dam 1E foundation

Drilling and grouting for Borinquen Dam 1E using a Soilmec SM-8 rig