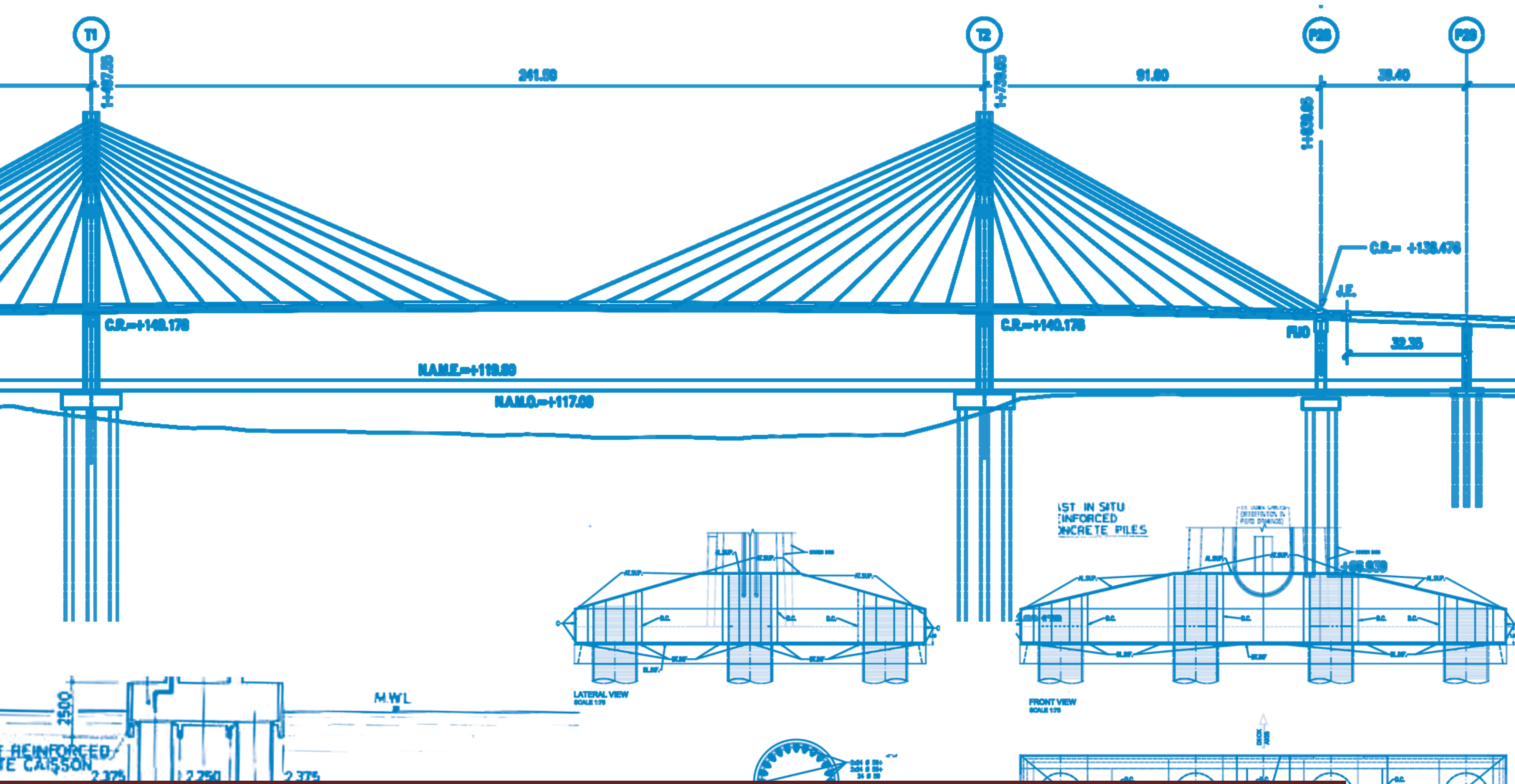


Trevi, global leader in bridges and causeways deep fondations construction

Bridges & Causeways

TREVI

The Group

Today, Trevi Group is worldwide acknowledged in the field of foundation engineering thanks to the field experience it has acquired, the technology it uses, the constant ability to find timely new and innovative solutions on complex civil engineering needs *(thanks to the never ceasing integration and interchange among the two divisions Trevi and Soilmec)*, and for its predisposition to integrate and collaborate with the local cultures.

The Group has been listed on the Milan Stock Exchange since 1999.

Trevi

Trevi has managed to satisfy the multifaceted requirements of foundation industry, always showing a positive approach towards cultures different from its own. In this way, Trevi has succeeded in developing innovative global technologies - thanks to practical and first-hand analyses carried out by skilled professionals and experts - as well as modern and streamlined production systems; the teams' hard work spread out across faraway lands and was held together by shared values and by a passion that knows no borders. Nowadays, Trevi is one of the major world leaders in foundation engineering. Trevi is extremely dynamic thanks to the continuous search for new solutions to the complex problems currently being tackled by civil engineering around the world.

What are TREVI's strong points?

The ability to work in different scenarios, the willingness to challenge its own knowledge by dealing with other engineering cultures, a flexible management of human resources - by means of a continuous training -, the importance given to a positive and stimulating work environment, the choice of making its branches work autonomously and take operating decisions while never ceasing to follow the guidelines defined by the mother company.

Which targets? Safety, quality, efficiency, specialization, flexibility.

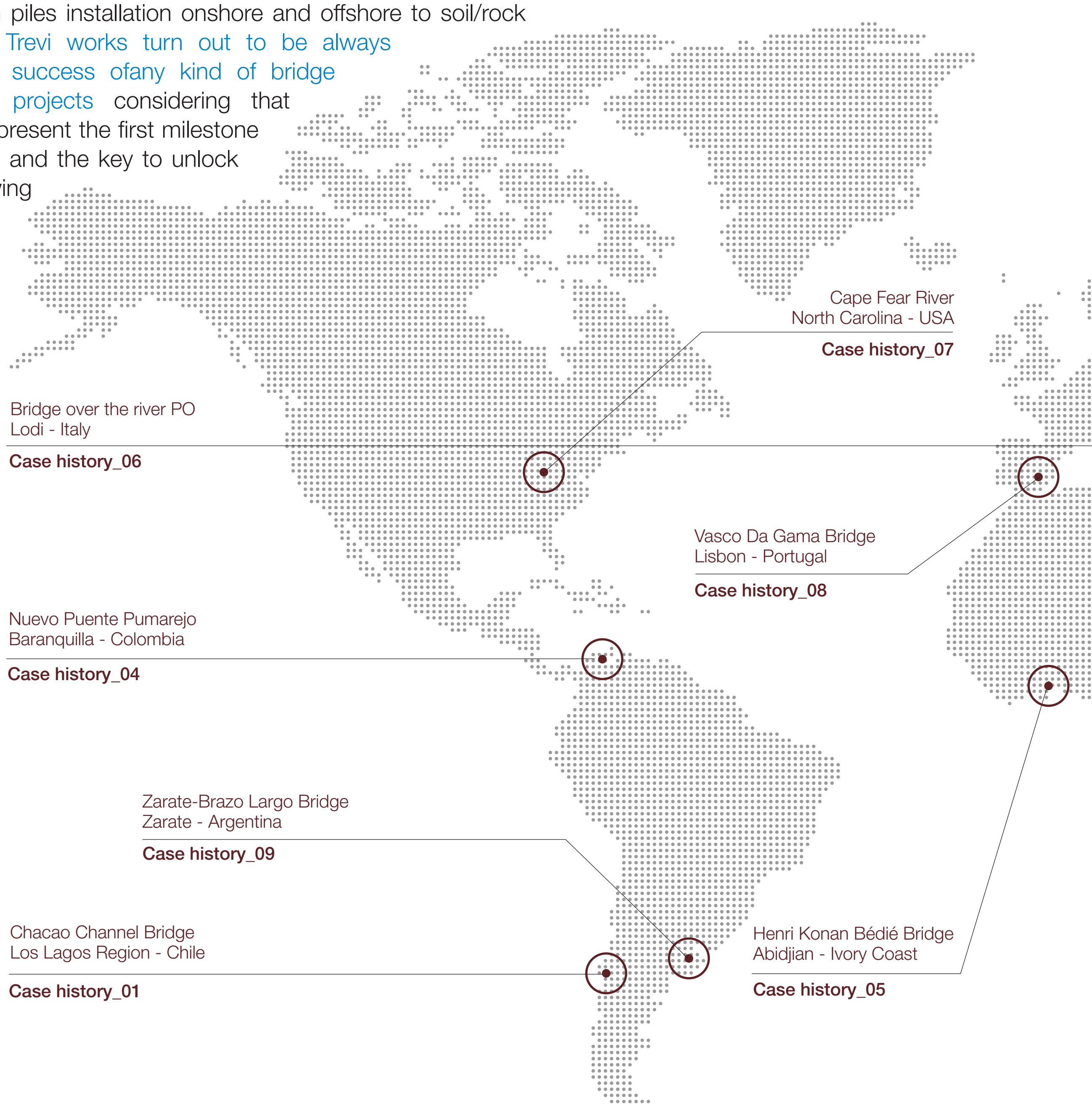
Cover: **Sheikh Jaber Al-Ahmad Al-Sabah Causeway - Kuwait**
Picture on the right: **Vasco Da Gama Bridge - Portugal**

Global leader in bridges & causeways foundations construction

Since ancient times, bridges have been a fundamental link between two sides separating two land portions and sometimes even two cultures.

Nowadays, technological evolution is driving the construction of impressive bridges that are increasingly daring in terms of length, height, slenderness and building time. In the wake of these escalating goals the foundation construction industry is striving to push the envelope to cope with the increasing challenges deriving from this "new bridge era". At the same time, many developing countries are investing in the realization of hundreds of new bridges to improve the connection to areas which are still isolated from globalised economic opportunities.

Within this context, the presence of the Trevi Group in the bridge sector is really significant, especially in the light of a long tradition, which dates back to more than half a century. Spanning from piles installation onshore and offshore to soil/rock consolidation, Trevi works turn out to be always crucial to the success ofany kind of bridge or causeway projects considering that foundations represent the first milestone of the process and the key to unlock all the following construction phases.



Trevi benefits from a unique experience and know-how, derived from the contribution to many of the most complex and iconic projects carried out on the five continents, and has become one of the worldwide leading companies to be preferably involved whenever a bridge construction requires expertise, cutting-edge technologies, innovation and flexibility. In particular, off-shore piling represents a flagship for Trevi, being a technology where a very large know-how has been developed during decades with the help of generations of engineers, site managers, operators and workers.

With the involvement in almost 300 projects worldwide, Trevi has consolidated its technical and technological leadership in the execution of special foundation works for any type of bridge. Among the many projects carried out by Trevi, it is worth mentioning the following places where the company participated in the construction of major bridges, causeways and viaducts: Lisbon (POT), Kuwait City (KUW), Baranquilla (COL), Zarate (ARG), Hong Kong (HKG), Cebu City (PHI), Nizhniy Pyandzh (TJK), Manila (PHI), Lodi (ITA), Lagos (NGR), Abidjan (CIV), Bissau (GBS), Istanbul (TUR), Porto Novo (BEN), Tete (MOZ), Gabon, Santa Rosa Beach, FL (USA),Constantine (ALG) and the very last Pargua-Chacao (CHI).

Chacao Channel Bridge
Los Lagos Region - CHILE

Owner:	MOP - Ministry of Public Works of Chile
Main Contractor:	CPC (Consorcio Puente Chacao)
Completion Date:	2018 - 2020

The **Chacao Channel Bridge is considered one of the most important, imposing and strategic projects in South America**, strongly desired by the Chilean Government to connect the great island of Chiloé to the continent, crossing the Chacao Channel.

The Chacao Channel Bridge is located 1100 km south of Santiago, in the "lakes" region.

At 2750 metres, the Chacao cable-stayed bridge will be third in length only to the Great Bridge of the Akashi Strait in Japan and to the Storebælt in Denmark.

Trevi Chile has been recently assigned the offshore foundation works, **bored piles with a diameter of 2500/2800 mm to a depth of about 90 m**, within an environment made particularly difficult by both sea currents and winds, which have a great impact on the work operations.

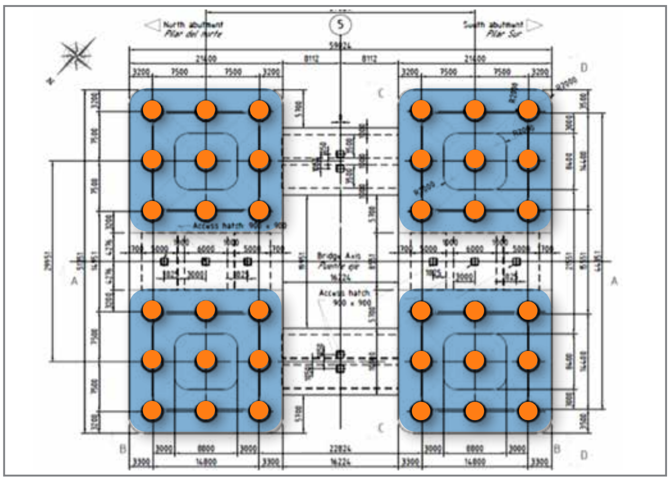
Out of a total of **54 concrete piles on water**, **36 piles will be the foundation of the central pier and the remaining 18 of the northern pier.** The drilling operations are executed by a jack-up barge. In addition, 2 preliminary test piles *(one for each pier)* will behave been drilled to check the conditions of each pier area. The piles are drilled by means of a Soilmec crane SC-120 equipped with a hydraulic rotary SA-40.

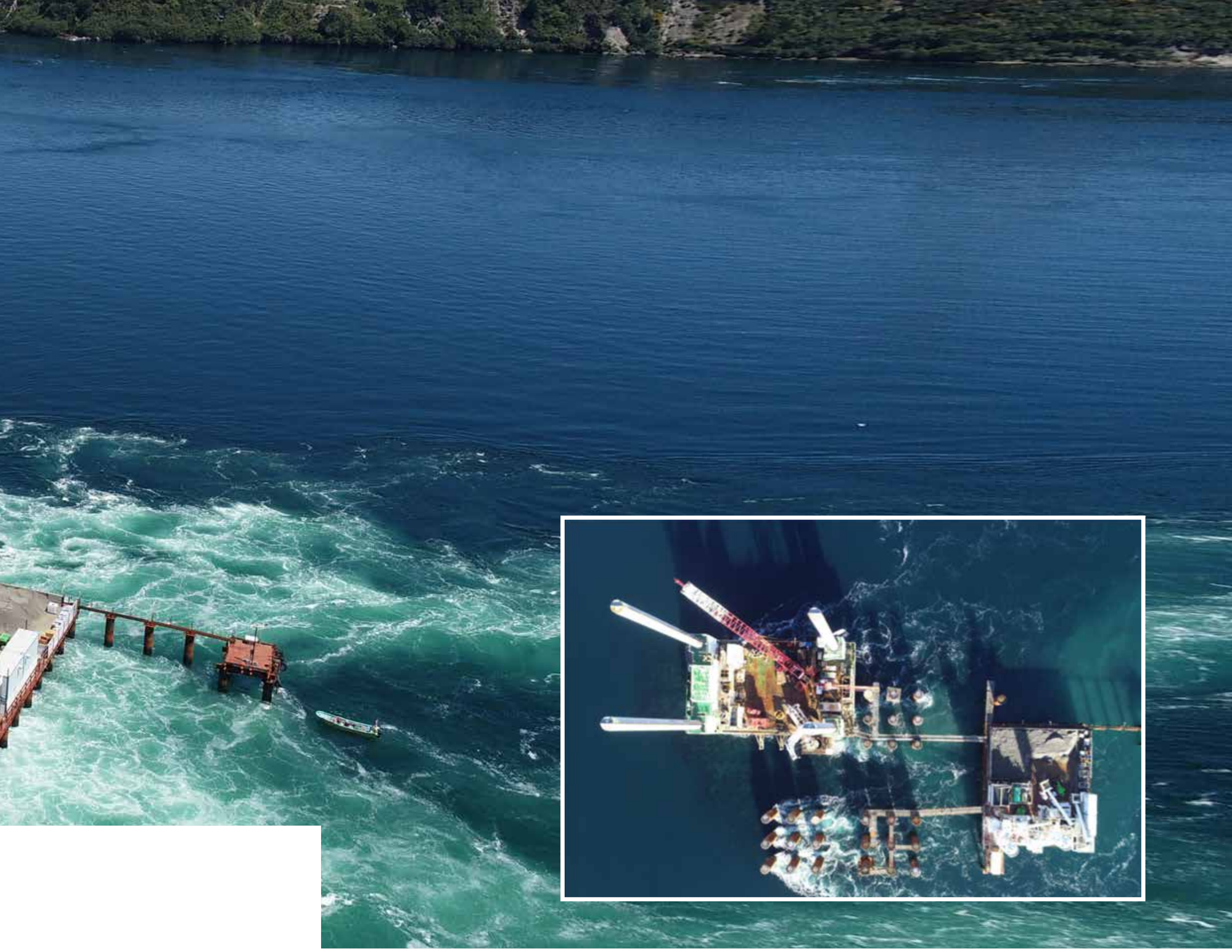
A 400 tons lifting crane is used for positioning the guide frame, for driving the steel structural liners, installing the reinforcement and for the casting operations. In addition, this equipment is also used to join the liners and fix them in a single solution.

A 300 tons jetty crane is used for handling the liners during the welding operations and for loading the reinforcement cages from trucks and barges.

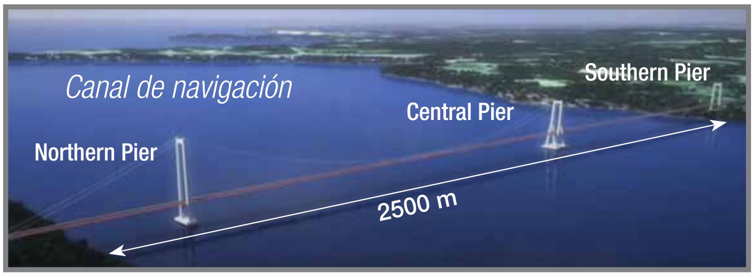
A 250 tons crane for the site area, is used for handling reinforcement cages during the assembly operations, and for loading/ unloading cages and liners from transport trucks.

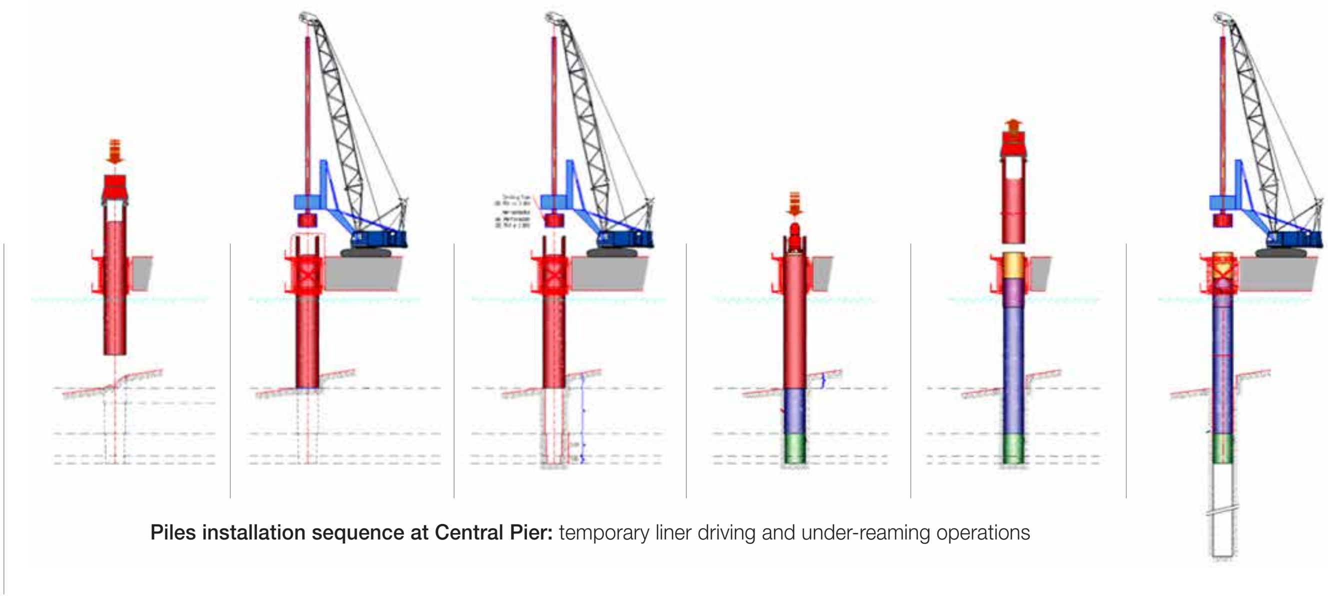
A 600 tons crane is used with 50/60 tons hydraulic hammer



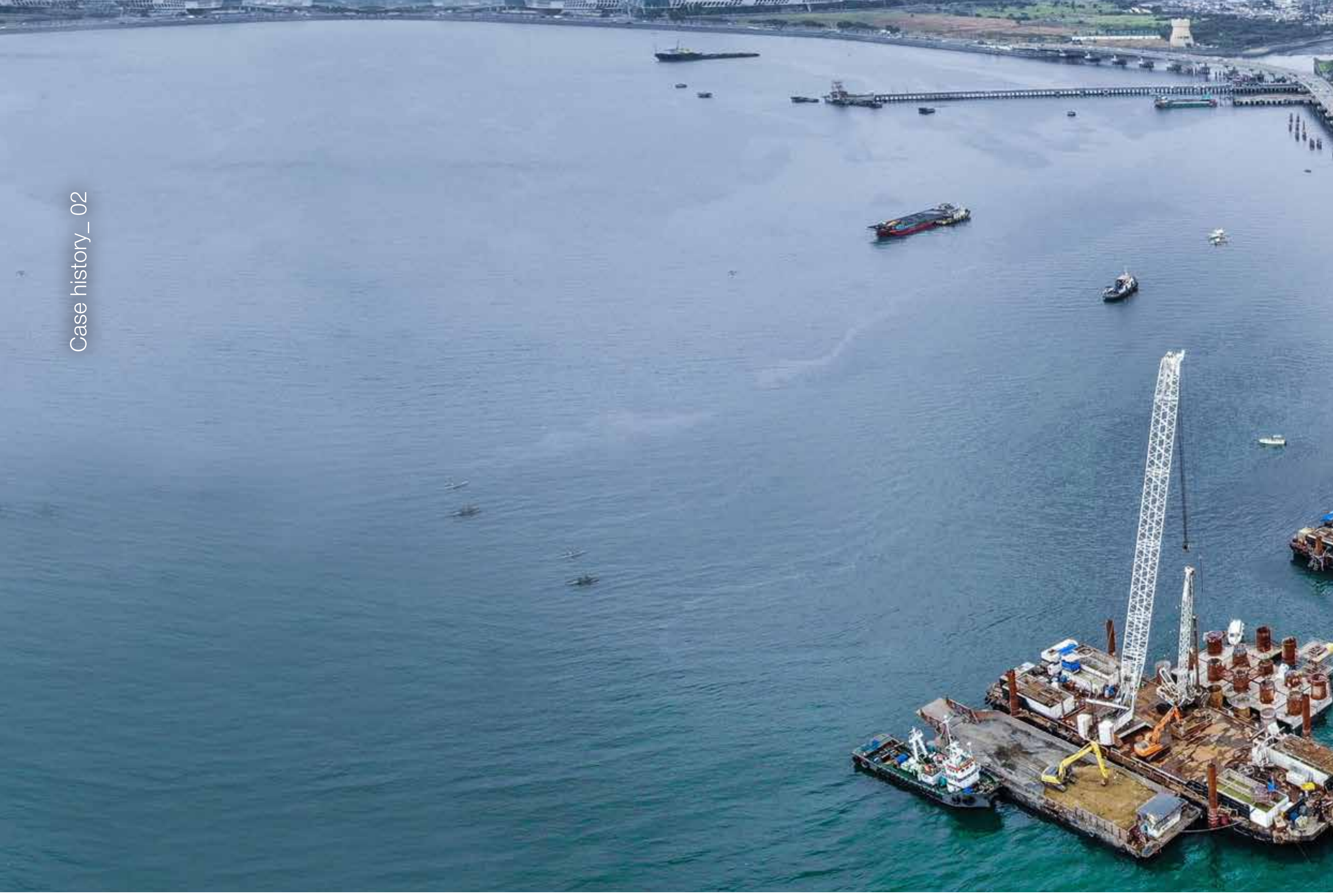


to drive the casings on the North Pier while the drilling is carried out with the reverse circulation technology.
A hydraulic vibrator is used to insert the temporary and permanent casing whose variable thickness reaches the remarkable value of 79 mm.
In the area adjacent to the embankment of the Chacao Channel Bridge, a shed has been built for the welding operations of the casings, representing a critical aspect of the project. The welding process has been completely automated using the “submerged arc” welding system.





Piles installation sequence at Central Pier: temporary liner driving and under-reaming operations



Case history_ 02

Cebu-Cordova Link Expressway
Cebu City, PHILIPPINES

Owner:	Metro Pacific Tollways Dev. Corporation
Main Contractor:	Cebu Link JV (Acciona, First Balfour, D.M. Consunji Inc.)
Completion Date:	2018 - 2020

Trevi Foundations Philippines, Inc. is completing the installation of deep foundations for one of the most important and crucial road projects in the Republic of the Philippines, the Cebu-Cordova Link Expressway (CCLEX), which will directly connect the main industrial area of Cebu City to Mactan International Airport and the new rapidly developing areas of the city of Cordoba.

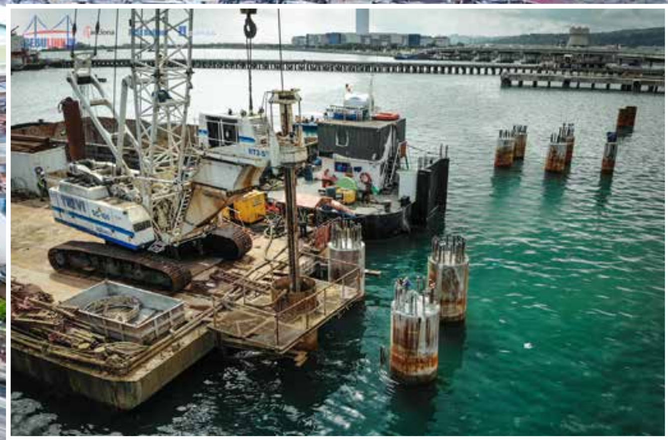
This project, costing about 500 million US dollars, will completely revolutionize road traffic between the islands of Cebu and Mactan, which are currently connected by two bridges continuously congested by vehicular traffic.

Metro Pacific Tollways Development Corporation (MPTC), in collaboration with the municipalities of Cebu and Cordoba, was awarded the CCLEX contract under the construction and management scheme of the public-private partnership program developed by the Philippine government. MPTC entrusted the construction of the project to its own subsidiary, Cebu-Cordova Link Expressway Corporation (CCLEC), which was created specifically for this development. **MPTC's objective is to halve the actual travel time from the island of Mactan to Cebu and vice versa, so as to attract an initially estimated 40,000 to 50,000 daily users.**

The development of the project was then contracted out to Cebu Link Joint Venture (CLJV), a temporary association of companies set up by the Spanish company ACCIONA Construction S.A., and the Philippine companies D. M. Consunji, Inc. and First Balfour, Inc.

The Cebu-Cordoba Link Expressway Project (CCLEX) will realize a new motorway, with two lanes in each direction, which will mainly travel over intertidal coral reefs and cross the Mactan Channel via a high cable-stayed bridge (Cebu Bridge) connected to the mainland by long viaducts.

In detail, the Cebu-Cordoba Link Expressway Project (CCLEX) consists in a new motorway, with two lanes in each direction, which will mainly travel over intertidal coral reefs and cross the Mactan Channel via a high cable-stayed bridge (Cebu Bridge) connected to


the mainland by long viaducts.

The Cebu Bridge will be a cable-stayed bridge with two central towers reaching a height of +145.00 m above medium sea level, due to restrictions on the authorization of air navigation; and both the central towers and the rear piers will be supported by deep foundations.

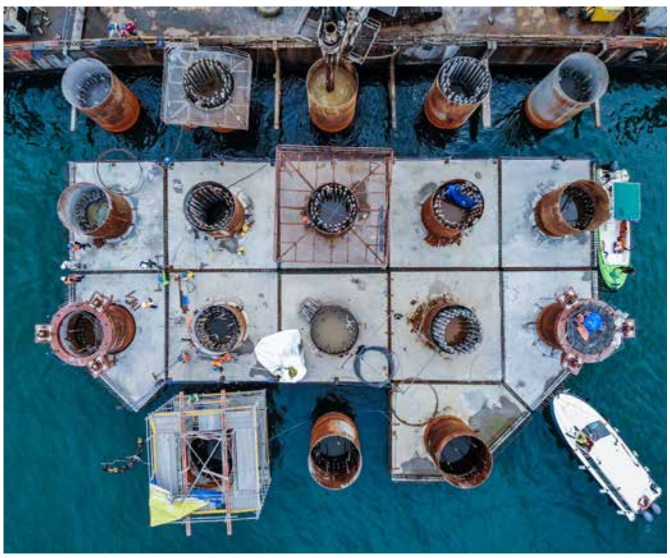
Trevi Foundations Philippines, Inc. was chosen as the specialist subcontractor for the construction of the deep foundations of the CCLEX.

The contract awarded to Trevi Foundations Philippines, Inc. involves the **installation of more than 450 piles**, most of which are installed offshore, for a total drilling length of more than 13,000 linear meters and diameters ranging from 1.0 m to 2.5 m.

These piles, with lengths ranging from 11 to 70 m, will transfer the entire load of the superstructures into the deep soil layers in order to ensure structurally admissible settlements and an adequate safety factor. **The greatest technical challenge that Trevi has been facing so far, is the execution of long and large diameter piles in the middle of the Mactan Channel, often congested by busy traffic.** Most of the route is located inside the Mactan Channel and the neighbouring intertidal coral reefs where there are thick layers of limestone *(Carcar Limestone)* and quaternary alluvial deposits. Marl intercalations and reshaped areas have also been observed.

The **most challenging part of the project is certainly represented by the execution of the piles for the two towers of the Cebu Bridge, where the larger piles have to be installed in the middle of the Mactan Channel.** The heavy steel cages, with a high number of 50 mm coupled re-bars, all of which had to be joined by coupler sleeves, have made the operations even more arduous. In order to shorten the timing and increase the precision in the installation of the reinforcement cages, Trevi has studied and developed a special system called **H.C.T.S. *(Hydraulic Catapult Trevi System)*** which has been fabricated and is being successfully used during the lifting operations.

For the offshore operations, three barges are being used, suitably sized and equipped according to the specific activities assigned.



Causeway Project (Sheik Jaber Al-Ahmas Al-Sabah)
Kuwait City, KUWAIT

Owner:	Ministry of Public Works (MPW) Kuwait
Main Contractor:	HYUNDAY Engineering & Construction Co.
Completion Date:	2015 - 2018

The local Trevi Group company, Trevi Foundations Kuwait, was involved in the construction of the Sheikh Jaber Al-Ahmas Al-Sabah Causeway in Kuwait City, named after the late Emir of Kuwait.

The project, worth around US$ 3.7 billion, provided for the construction of a **37 km long causeway across Kuwait Bay**, linking the Port of Shuwaikh with the Town of Subiya, and was the first phase of a larger investment programme within the framework of the new Silk City. In addition to the causeway, the project also included a bridge with a 200 m span, an elevated road, access roads to the Subiya area for a **total length of 5 km and two artificial islands**, both extending around 30 hectares.

The main objectives of the project were:

• to cut the travel time across the bay to less than 30 minutes (today it takes around 90 minutes to cross the bay, following the coast road);

• to create new motorway routes to enhance the development planned to the north of Kuwait City;

• to encourage greater integration between the northern areas of the country and the central and southern districts which are densely populated;

• to reduce traffic congestion in the surrounding major roads.

The Combined Group Contracting Company (CGCC), a Kuwaiti contractor specialised in oil and gas pipeline installation and in road and tunnel construction, and the Hyundai Engineering and Construction Company Ltd. (HDEC) from Korea, were the two project contractors. The project, which began in November 2013, was scheduled to take 1827 days, approximately five years, and was completed in 2018.

Trevi Foundation Kuwait was awarded a contract from the two contractors for the execution of 760 piles, both onshore and offshore, out of a total number of 1,200.

The piles, bored with stabilising fluid to support the excavation, had a **diameter of 2500 mm onshore** and **3000 mm offshore**, with depths **ranging from 30 m to 84 m**. Due to environmental restrictions, biodegradable polymers were used in the stabilising fluid.

The soils along the causeway axis consisted mainly of sand *(ranging from loose to very dense)* and clay *(ranging from very soft to soft)*, even though shallow layers of caprock with fossils, cemented sands or cemented quartzitic gravel could be found at times in the stratigraphic cross sections.

Several unusual and interesting solutions were arranged for this specific project.

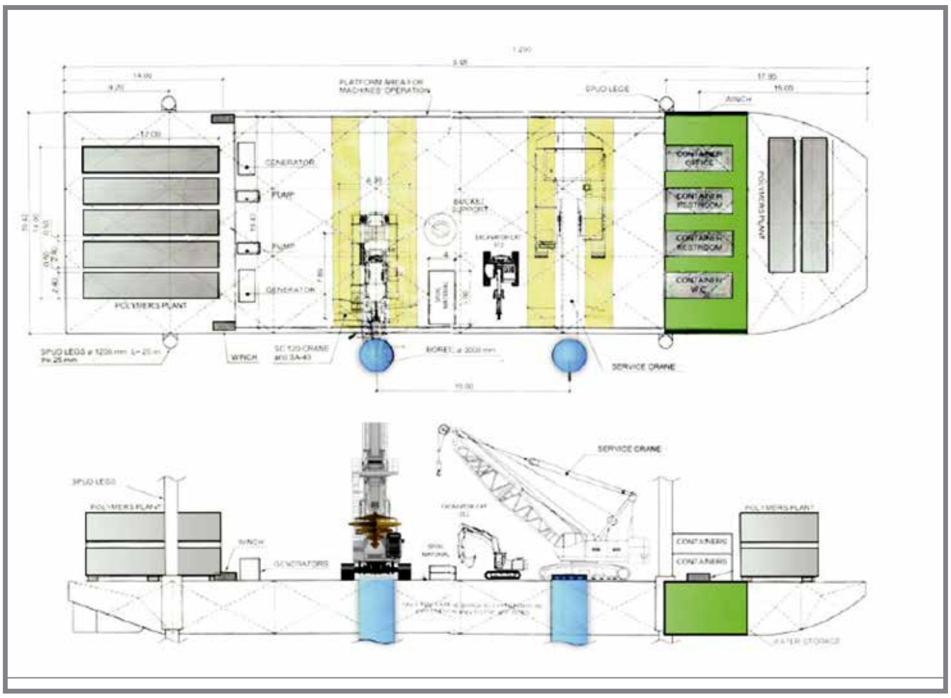
To install the offshore piles, a pontoon, approximately 20 m wide and 74 m long, was set up; it was positioned by tugs and anchored to dead weights which had been placed on the seabed. Four steel spuds were lowered onto the seabed to stabilize the pontoon once it had been manoeuvred into position. The debris produced during the excavation were discharged directly into

watertight caissons and then removed from the jobsite without polluting the water in the bay. A tank was mounted underneath the working platform set on top of the pile casing to catch any possible leakage of stabilising fluid which might overflow when the excavation tools were manoeuvred and when the reinforcement cage was installed and the concrete poured.

The vertical bars had to be connected by means of threaded couplers so that the cage sections were constructed using special tools to ensure the correct positioning of all the bars.

When casting a pile in water at a maximum depth of 84 m, 594 m^3 of concrete were needed.

The solution chosen was to use two pontoons, each with a batching plant; both pontoons also had a concrete pump whose spraying arm was long enough to reach the pile. To speed up the casting process, an oversized tremie pipe *(343 mm in diameter)* and a funnel with a capacity of 1.6 cubic metres were used, guaranteeing a capacity of up to 80 m^3/h.



Nuevo Puente Pumarejo
Baranquilla - COLOMBIA

Owner:	INVIAS - Instituto Nacional De Vias
Main Contractor:	Consorcio SES Puente Magdalena
Completion Date:	2015 - 2016

One of the most interesting bridge projects in Latin America in recent years was the iconic Pumarejo Bridge in Barranquilla, Colombia. The National Institute of Roads of Colombia (INVIAS) awarded the construction of a new bridge over the Magdalena River to the consortium SES Puente Magdalena Bridge *(formed by Sacyr Construcción Colombia SAS, Sacyr Chile and Esgamo Ingenieros Constructores)*, with an investment of US$ 237 million.

This new infrastructure resulted in the fundamental modernization of the passage over a river of great depth which will be adequate for the coming decades, as well as in the expansion of the port capacity for exports and imports, which in turn has increased the competitiveness and economic strengthening of the Country.

The new Pumarejo bridge started in Barranquilla, at the interchange linking with the road to the Port and with Santa Marta approximately 200 m from the K0 of the road, and reacheed the village of Palermo, 450 m from the river bank on its right bank. **The length of the bridge between abutments is now 2,280 m and 3,800 m** considering the different ramps, thus being the longest bridge in the Country.

According to the geological report, the Magdalena river valley was made up of alluvial and lagoon materials that had acquired a pseudo-stratified structure and form thick layers that could be divided into three main units. The shallow layers on the right bank of the river appeared as deposits of alluvial origin where loose or very weakly compacted sand could be distinguished. On the left bank the shallow deposits, of lagoon nature, were made up of clayey and sandy materials covered with surface layers of loose quartz sand. The deepest unit always corresponded to residual soils of sedimentary rocks composed of limestone, sandstone and claystone.

The project area was divided into three sectors: the first corresponing to the left arm of the Magdalena River *(main navigable channel)*, the second to Isla Rondón, the third to the access by the right margin, also known as Palermo.

The structural project for the crossing of the Magdalena River was subdivided into three main structures:

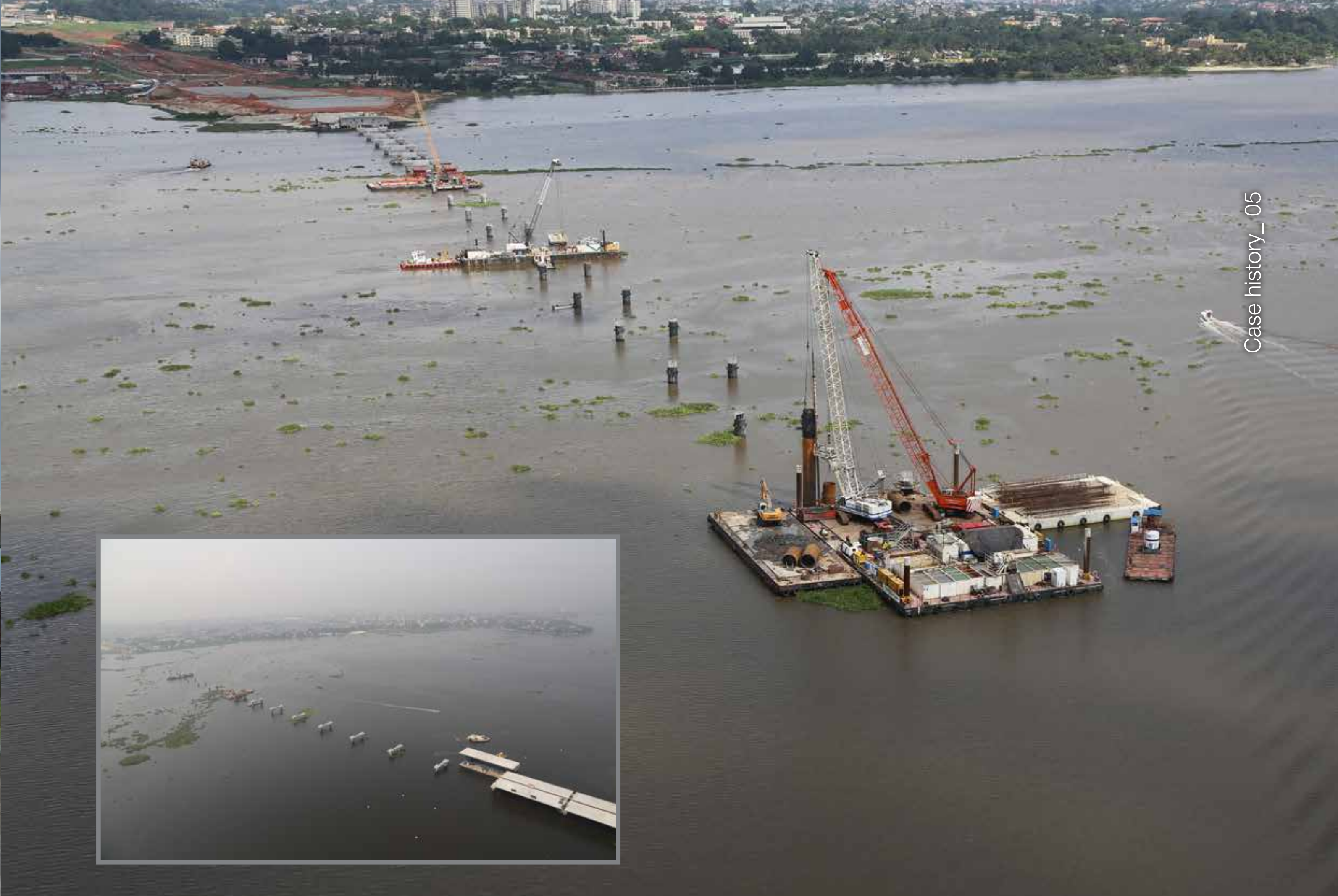
• a **cable-stayed bridge with two main piers with a main span of 380 m** and two compensation spans of 155 m<

• an access viaduct on the right bank with consecutive spans of 70 meters and 14 supports arranged over the areas of Isla Rondón;

• a third access viaduct from the left bank with spans between 32 and 70 meters, arranged with two ramps with 21 supports.

From a structural point of view the foundation was composed by 288 piles in total, with depths spanning from 25 m to 60 m, and diameters varying from 2.0 to 2.8 meters.

Among the several issues Trevi had to deal with during the pile construction process, it is worth noting that thick loose sand layers, up to a 20 m depth, were found within the Magdalena area, which forced the use of steel casings to assure the borehole stability.



Henri Konan Bédié Bridge
Abidjan - IVORY COAST

Owner:	Ivorian government
Main Contractor:	Bouygues Group (SACPRM)
Completion Date:	2011

Henri Konan Bédié Bridge is a box girder structure in usage as road bridge and expressway linking the north and south of Abidjan and is currently the longest in Ivory Coast with a 1.5 km (0.93 mi) long viaduct crossing the Ébrié Lagoon and connecting the districts of Cocody and Marcory.

Built, financed and operated as a Public-private partnership (SOCOPRIM), the toll bridge is the third major road crossing of the Ebrié lagoon and was designed to reduce congestion on its two predecessors, the Houphouët-Boigny Bridge and the Charles de Gaulle Bridge, constructed in the 1950s and 1960s respectively.
In 1997 the Ivorian government signed a concession agreement with a consortium headed by the Bouygues Group (SACPRM) for the construction and operation of the bridge and associated expressway project. Due to political instability, major work on the project only got underway in 2011 when new contracts were signed, allowing the re-launch of the construction site marked by a new official ceremony on September 7, 2011.
Its construction was accompanied by the realisation of that of a new three-level interchange on the Boulevard Valéry Giscard d'Estaing.

The entire project consisted of three parts:

- the **northern part on the Riviéra side**, 2.7 km long in 2x2 lanes from Boulevard Mitterrand to the edge of the Ebrié Lagoon;
- the **Henri-Konan-Bédié Bridge**, 1.5 km long in 2x3 lanes, 28 m wide, including a 3 m sidewalk, and with deep foundations ranging from 30 m to 90 m, connecting the Riviéra dike to the Marcory shoreline;
- the **southern part on the Marcory side**, 2 km long in 2x3 lanes, connecting the lagoon edge to Boulevard Giscard d'Estaing and to the eponymous interchange.

The contract was awarded to Trevi SpA by the SACPRM consortium. Piles base injection was part of the scope of work and was executed on the bored piles through specific tubes inserted inside the shaft at the time of casting.

The soil stratigraphy was mainly formed by a very soft mud shallow layer underlain by alternating clayey sand and dense sand strata.

- **Bored Piles ø 2000 mm.**, max. depth 92 m, were performed on water from floating pontoon for the piers of the bridge.

- **Bored Piles ø 1000-1200-1400 mm**, were performed on land for piers/abutments of the bridge/ramps.

- **Steel Sheet Piles** were installed to create a wall for the temporary jetty. Vibro-flotation was applied to consolidate the soil for ramp accesses and bridge's abutment.

River Po Bridge High-speed Railway Line Milan-Bologna
San Rocco (LO) - ITALY

Owner:	RFI - TAV
Main Contractor:	CEPAV UNO Consorzio Aquater, Snamprogetti e Grandi Lavori Fincosit
Completion Date:	2002 - 2006

The Milan-Bologna high-capacity/high-speed railway line stretches 182 km from Melegnano to Lavino, crossing the Po Valley and the provinces of Milan, Lodi, Piacenza, Parma, Reggio Emilia, Modena and Bologna. By transferring long-distance traffic into the high-speed line also short and medium distance traffic and rail freight service was enhanced, thus doubling the previous transport capacity.

The new high-speed Milan-Bologna line crossed the Po River near Piacenza, at San Rocco al Porto (LO); **the total distance between the main embankments was about 1343 metres, with a 400 m wide section to cross the ordinary riverbed.**

Two viaducts 4 and 5 km long and leading to the main embankments, completed this impressive project. It was estimated that 471 trains would pass over this bridge every day at 300 km/h.

Thanks to its special engineering and architectural features, this bridge over the River Po was one of the most advanced railway construction projects in Europe. The bridge represented a new direction for railway viaducts, especially in Italy, not only because of its size, but also because its structure was in prestressed reinforced concrete. Indeed, it was one of the largest of its kind in the world, with a 192 m main span, a record for cable-stayed railway bridges in prestressed reinforced concrete.

The bridge over the River Po was designed in such a way that high-speed trains, reaching speeds of over 300 km/h, could cross it safely, thanks to a flexible deck consisting of an approx.4.5 metres high continuous open box girder, with a fixed point on one of the two towers and sliding bearings on the other tower and on the river bank piers.

Each of the two piers was supported by 28 piles with a diameter of 2.0 m and a length of 65 m.

The Trevi Group was involved in the construction of the piles on the riverbed and on land *(floodplains)* and in the retaining works to build the two artificial islands from where the piles on the riverbed were built and all the civil engineering works for the construction of the two piers were carried out.

Cape Fear River
North Carolina - USA

Owner:	State of North Carolina
Main Contractor:	xxxxx
Completion Date:	xxxx

Due to excessive traffic volume in the Wilmington downtown area and particularly on Market Street, the state of North Carolina decided to build, in segments, a 27-mile-long bypass that would eventually connect US 117, NC 132, US 421 and US 74/76. The project spanned Pender, New Hanover and Brunswick counties.

In particular the project included a **3.9 km (2.4 mile) bridge over the Northeast Cape Fear River near the North Carolina coast.** This bridge included about 500 drilled shaft foundations.

The shafts ranged from 1.2 m to 2.4 m diameter and lengths typically ranged from 22 in to 30 m to bear into a dense silty sand known locally as the Pee Dee Formation.

Soil Conditions were composed of silty fine sands. The alluvial sands above -11 m were considered as subject to scour during the design loading (includes hurricane conditions) and were not considered for design.

Installation of Drilled Shafts

All work was performed from temporary trestles over the wetlands and the East and West Cape Fear River channels. No spoils, slurry or fuel could be allowed from the trestle into the wetlands.

Each shaft was constructed using a permanent steel liner to elevation -13.8 m. The shafts also utilized a larger diameter isolation casing to elevation -10.8 m to separate the scourable overburden materials through this zone.

The shafts were constructed using a **Soilmec R-825** hydraulic track mounted drill rig. The excavation within the bearing formation was made using a drilling bucket with soil cutting *(spade type)* teeth that extended to a width beyond the diameter of the bucket.

The base of each shaft was cleaned using a flat bottom bucket, followed by a hydraulic pump. Following cleanout, the base was inspected using a downhole camera and sediment measurement system (mini-SID). Shaft bottom cleanliness was controlled to have less than 12mm of loose material at the base.

Competing and coordinating with the general contractor for the use of the train for required services along with 'runny' alluvial sands near the tip of the casings, encountering wood obstructions, working off a narrow trestle, strict adherence of specifications and `overuse' of Mini-SID were only a few of the many daily challenges TSI faced on the job.

However, this project has proven to be a success story throughout North Carolina and the Southeast. Installing drilled shafts in this environmentally sensitive area is challenging to say the least, but has turned out to be a great achievement.

Vasco Da Gama Bridge
Lisbon, PORTUGAL

Owner:	GATTEL (Lisbon)
Main Contractor:	NOVAPONTE ACE (Lisbon - Portugal)
Completion Date:	1995 - 1996

The construction of the Vasco da Gama bridge over the River Tagus, opened to traffic in March 1998, was one of the largest civil engineering projects in Europe at that time.

The bridge was of great benefit by alleviating the traffic congestion of the Lisbon's city centre and providing a new route for vehicles travelling between northern and southern Portugal. In addition, the bridge provided direct access to the site of the Universal Exhibition 98.

The bridge, which carried six traffic lanes, three in each direction, was made up of viaducts for about two thirds of its total length of about 18 km: about 10 km were on water and the rest on land.

Three navigation channels were provided whose the main one allowed the passage of large vessels, with a DWT up to 30.000 tons, under a cable-stayed bridge, which assured a clearance of 45 m above the high water level.

Strict environmental protection rules were adopted for the protection of the river ecosystem and for the recovery of the Samouco salt pans, in the southern area, to become a Nature Reserve.
Starting from the North, the Project could be subdivided into four main parts:

- Expo Viaduct, on land, 670 m long;
- Main Bridge, on water, with two piers of 150 m in height, with a main central span of 420 m and two side spans of 205 m;
- Central Viaduct, on water, which is extended for 6.5 km and included the two navigation channels of Cala de Barcas and Samora;
- South Viaduct, on land, with a length of 3.85 km, which included service areas and the Montjio crossings.

In April 1994, the 30 year BOT Contract was signed between Gattel, a Portuguese Body depending on the Ministry of Transport

Bored piles off shore:	**148** (ø 2200 mm) **124** (ø 2000 mm)
Steel sheet piles:	**16.400**
Driven piles:	**110**
Dredging:	**80.000**

and Lusoponte, an International Consortium formed by Trafalgar House (GBR), Campenon Bernard-SGE (FRA), and six Portuguese Companies: Bento Pedroso, Mota & Companhia, Somague Construcoes, Teixeira Duarte, H.Hagen and Edifer.

The average tide excursion was about 4 m and the whole area interested by the bridge construction was dredged up to -2.00 m below the lowest tide level, in order to facilitate the maritime transport for the bridge construction.

After the execution of several preliminary load tests, the final design defined two types of deep foundations:

• Large diameter bored piles for the areas of Expo Viaduct, Main Bridge and South Viaduct. The pile diameters of the viaducts on land varied from 800 to 2.200 mm, while for the Main Bridge 2.200 mm diameter piles were adopted.

• Steel driven piles for the Central Viaduct, excluding the piers next to the navigation channels of Cala de Barcas and Samora, where 2.200 mm diameter bored piles were adopted as well.

The piles toe level was designed to lie within sand and gravel layers, or within the underlying Pliocene sands, hence the total pile length was variable from 55 to 73 m. The upper portion of the pile was contained in a permanent steel casing, located mainly within over-consolidated silty clay layers.

In September 1994 **TREVI was awarded the contract for the installation of a single pile for a preliminary offshore load test up to 2000 ton, of 148 bored piles (2.200 mm in diameter and 70 m depth from MSL) for the Main Bridge and of 60 bored piles (2.000 mm in diameter and 79 m depth from MSL) to support the South Viaduct piers.**

Trevi adopted again SOILMEC equipment that proved once more their peculiar advantages: high excavation rate and high reliability.

Zarate - Brazo Largo road/rail complex
Zarate, ARGENTINA

Owner:	Metroselskabet I/S
Main Contractor:	Techint Albano (Buenos Aires) Pilotes Trevi
Completion Date:	1971

The Paranà river is divided into two large branches: the Paranà Las Palmas and the Paranà Guazù. In between the two rivers is enclosed the Talavera island with a width of about 20 km. The company Techint Albano was awarded the project and the execution of the foundations was entrusted to the company Pilotes Trevi.

The Zarate-Brazo Largo road/rail complex consisted of a series of viaducts and two bridges, the purpose of which was to connect the province of Entre Rios to the province of Buenos Aires.

The structure crossing both the Paranà river branches was a cable-stayed steel bridge formed by three spans: the two side spans 110 m long while the central span 330 m long. The height of the central span was designed to allow a clearance for the passage of 44.2 m above the lowest water level.
The bridge deck accommodated both a 22.5 m wide roadway and a 4.5 m wide railway track. The central piers of the main bridge were 70 m high above the road level, i.e. about 120 m above the river level. The impressive height of the main bridges was required for navigation whereas the necessity of large floodplains, in case of critical events, led to the construction of long viaducts.

The total length of the road/rail complex was around 16 km.

The soil stratigraphy was formed by a shallow muddy and peaty layer *(often quite deep)*, an intermediate layer of sandy silt and clay and a deep layer of dense sands.

The **viaduct design included the execution of 1040 piles with diameters of 2000 mm, 1600 mm and 1200 mm and with a length ranging from 35 m to 55 m**, because of the requirement of an embedment inside the dense sandy layers for a length equal to 5 times the pile diameter. **For the bridges, a total of 236 piles with a diameter of 2000 mm was installed on water with a length varying from 50 to 73 m.**

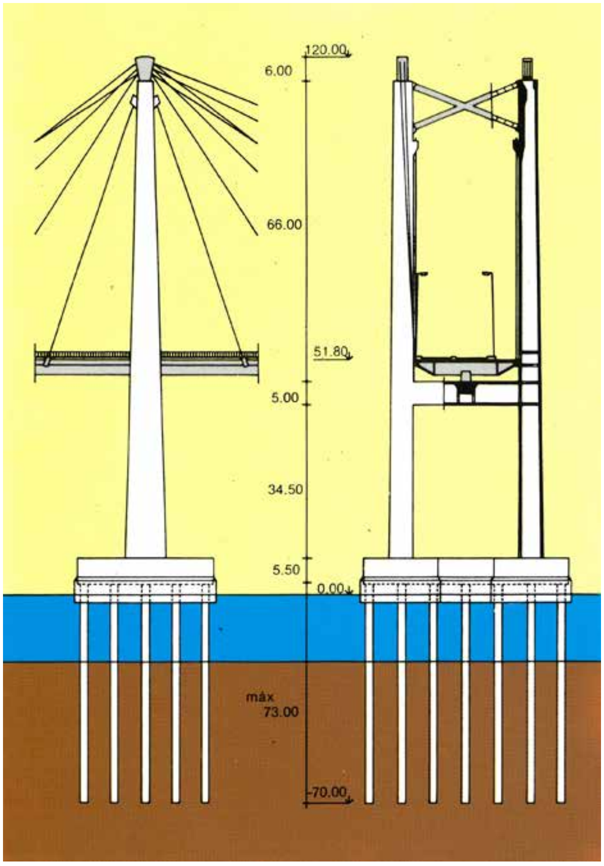
The entire shaft was lined with a 16 mm thick steel casing. In addition to the horizontal loads, a vertical load of about 1500 ton per pile was achieved according to the project requirements.

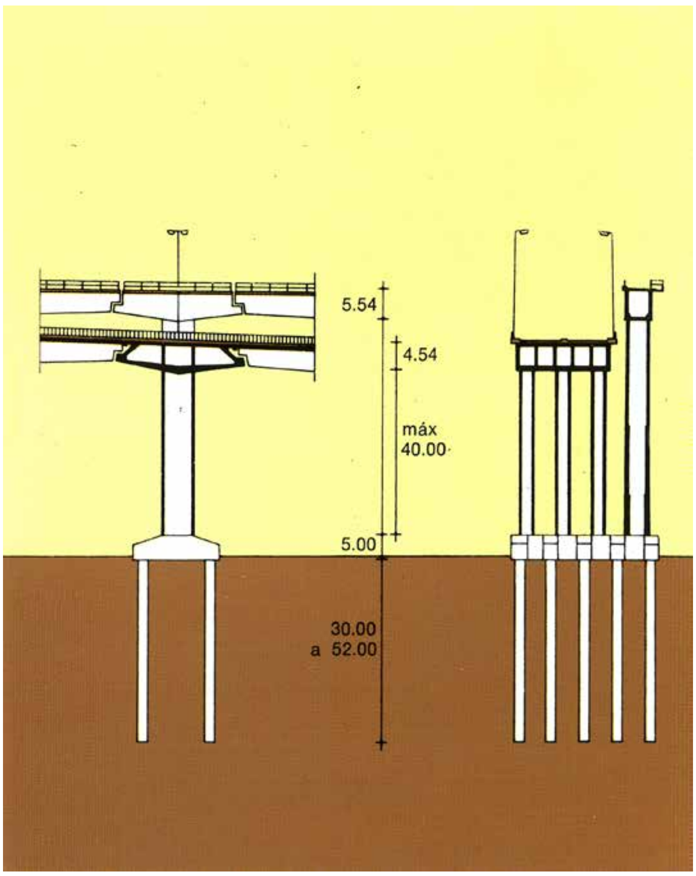
For the execution of the piles on water, the drilling equipment was operating on floating "T" shaped pontoons. Each pontoon was anchored by buoys to 6 dead bodies weighing 14 t each. The shape of the pontoon allowed simultaneous operations on two piles. The stability of the pontoons was obtained by filling some tanks, located atop, with bentonite mud and water.

One of the main problems faced during the drilling operations was caused by the great variability of the water level; in fact, the whole of the lower course of the Paranà river presented a significant tidal range.

In order to fully activate the base resistance a load cell was inserted at each pile base and pressurised before being connected to the upper pile concrete body by a final injection.

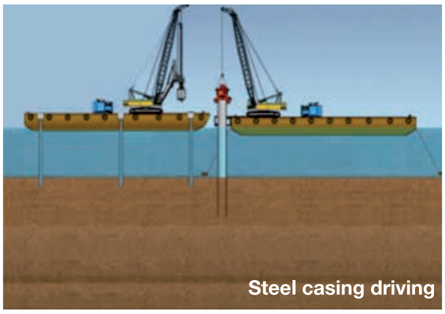
Bored Piles, viaducts:	n. 1040
Bored Piles, bridge:	n. 236

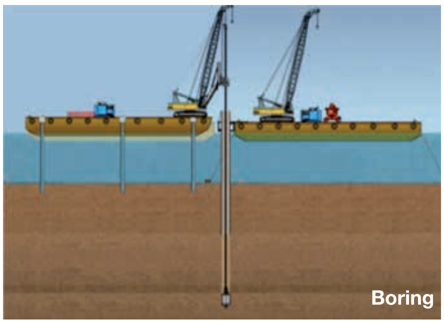


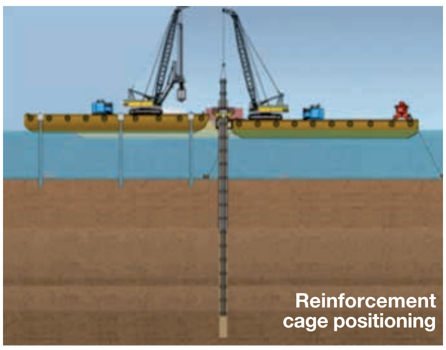


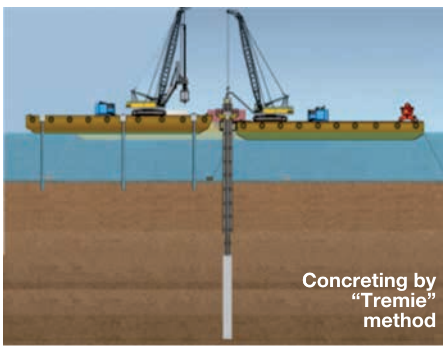
Offshore bored piles
for the construction of pier foundations for bridges and viaducts.

The main reasons for applying this technique is the presence of large loads associated very often to the requirement of drilling to deeper soil layers with better mechanical properties.


Steel casing driving


Boring


Reinforcement cage positioning


Concreting by "Tremie" method

Whenever bored piles are installed underwater, jobsite logistics, handling of excavation fluids and cuttings, supply of reinforcement cages and casting turn out to be as important as the drilling operations.

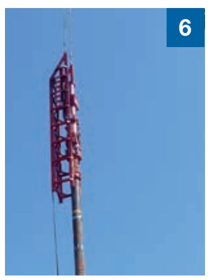
Planning the operational phases, designing accurately the layout of the working platform and assessing in advance the flow of supplies are critical aspect for the success of the project and for the respect of deadlines.

The most common system is formed by a hydraulic rotary, a Kelly bar and drilling tools. Standard equipment for pile drilling can be suitable for installing piles with a diameter up to 4 m and depth greater than 80 m and they can work on floating pontoons, barge restrained by spuds driven into the seabed or jack-up barges, depending on the water depth.

The first stage consists in driving a permanent steel casing into the seabed to a depth ensuring stability for the subsequent drilling. The casing is emptied by means of a bucket or short auger. The pile is drilled using a fluid to support the borehole up to the design depth. The next operations are: de-sanding the particles present inside the fluid, positioning the reinforcement cage and casting by means of the tremie pipe method.

Alternative to pontoons in shallow waters

When working in shallow waters, a possible alternative to the use of pontoons is to realize a temporary jetty to work on with the drilling equipment. The steel jetty is usually made following a modular layout of beams 7 m spans.
The jetty must be at least 8 m wide



to ensure easy movement of drilling rigs and handling of debris and raw materials.

The wharf construction starts off with the positioning of a temporary steel casing, usually driven or vibrated in-place, along the jetty axis (1). A support beam (2) is placed at the top of the casing to support a template (3) used for casting two piles (4) aimed at bearing the framework of the jetty.

The support piles are usually vibrated into the ground until refusal (5) and then driven by means of an electric hammer (6) until the required depth is reached.
When a pair of piles are cast in place, the template is removed and a jetty span is realized (7).

Other solution ... to pontoons in deep waters

When working in deep waters, a possible alternative to the use of pontoons is to use the same pile cap – to be constructed once piles have been completed – as work platform for the construction of the piers.
The pile cap can be either of steel or concrete: it shall be prefabricated in a dock and floated into place where the pier is being executed.
Temporary casings will be used inside the pile cap in the same positions of the foundation piles of the pile cap itself.

As the pile cap reaches the pier area, it shall be anchored to a number of temporary piles -steel piles either vibrated or driven into the seabed (fig.1).

Using a floating equipment, four permanent casings are lowered into place and firmly anchored to the pile cap walls (fig.2). They are needed to construct the piles.

The annulus between the casings positioned in this phase and the plates

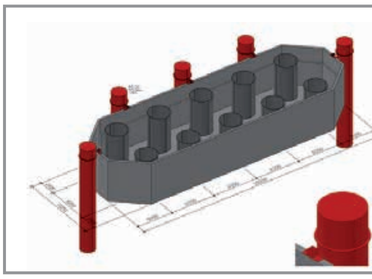


fig.1

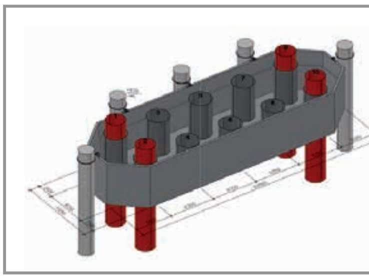


fig.2

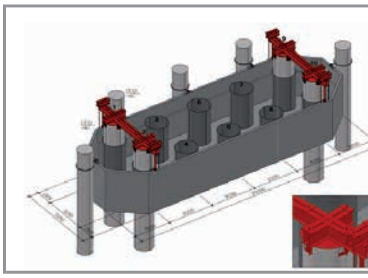


fig.3

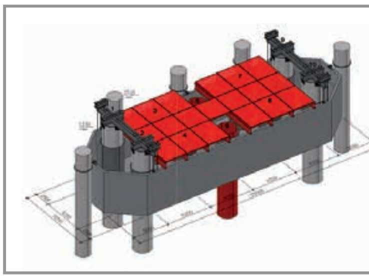


fig.4

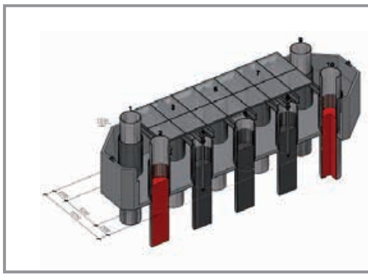


fig.5

pre-assembled inside the pile cap are sealed with cement mortar to improve the stiffness of interlocking between the two structures. The final operation consists in installing the working platform on which the drilling rig is operated to drill the piles (fig.3).

To drill the piles, portions of the platform are disassembled and repositioned from time to time to free the access to the work plate mouth (fig.4).

Once the piles have been completed, the platform is disassembled, the temporary plates are cut, concrete in the pile heads is trimmed and the whole pile cap is concreted, after inserting the steel reinforcement cage (fig.5).

Technologies special application
for bridge sector

OFFSHORE BORED PILES

This technology differs from the one used to drill piles on ground. Indeed, the execution problems associated with a harsh working environment - due to the presence of tides, bad weather, currents and so on -, require an organization capable of facing and quickly solving any possible issue.

BORED PILES WITH REVERSE CIRCULATION DRILLING

The reverse circulation drilling method is also known as air lifting drilling. Compressed air is introduced inside the drilling rod, just above the tool, hence reducing the density of the drilling fluid and creating a differential pressure that can lift the said fluid inside the rods. Mud and debris are then conveyed into a mud container.

STEEL PILES

Steel piles, with cylindrical or I-section are often installed in marine structures or as foundations for permanent bridges, temporary structures, acoustic screens and buildings with underground floors.

However, due to their numerous advantages, they are expected to grow in popularity soon.
We install steel piles using three technologies, depending on soil conditions:

- driving with hydraulic hammers,
- pressing in with hydraulic pressing units, and
- vibrating with vibratory hammers.

In case of large offshore structures (*e.g. harbour constructions)*, it is necessary to use special

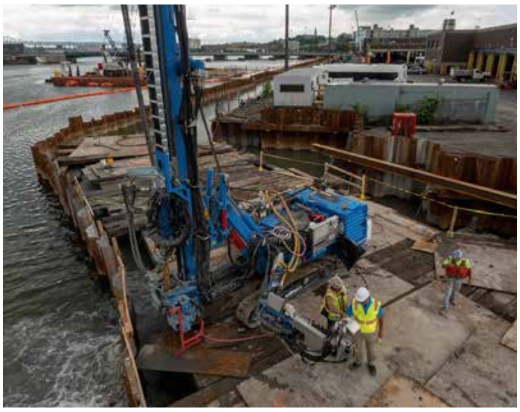
floating platforms supported by spuds extending down and inserted on the sea bed to ensure stability and safety during piling operations. Our piling equipment allows us to easily install steel piles longer than 20 m. Installation of steel piles with the vibration method is performed with modern resonance-free vibro-hammers. They operate in high frequencies, which allows to vibrate steel piles in close proximity to the existing buildings or other vibration-sensitive structures or installations. In case of sheet pile sections, it is also possible to use the hydraulic press-in method.

JET GROUTING

By means of the TREVIJET system it is possible to obtain columns with the following diameters:

- 0.35 - 1.00 m by means of TREVIJET T1
- 0.60 - 2.50 m by means of TREVIJET T1/S
- 1.40 - 3.50 m by means of TREVIJET T2

The said dimensions and mechanical features of the treated soil mostly depend on the combination of several elements, such as soil type, jetting parameters and composition of the grouting mixture.



SHEET PILING

Sheet piling technology is commonly used in many engineering fields. It is an advantageous solution for supporting excavations, for cofferdams on water and for marine works, just to mention a few of its several applications.

DYNAMIC COMPACTION

Dynamic Compaction (DC) is a a Ground Modification techniquee whereby loose soils can be effectively and economically densified to improve its mechanical characteristics and allow construction of structures directly on compacted soil, without need of deep foundations or soil replacement.
The method involves dropping heavy steel pounders repeatedly on the ground at regularly spaced intervals. The weight and height of pounding depends on the degree of compaction desired. The usual range of pounder weight is between 12 Ton to 25 Ton and the drop height can be up to 25 m.

Dynamic Compaction (DC) method is applicable for a wide variety of soil conditions including saturated/unsaturated loose Sands, even with the presence of silty pockets, dune sands, inorganic fill, reclaimed soils with variable characteristics and sizes even with the presence of large sized boulders, landfill deposits and collapsible soils.

Dynamic Compaction (DC) has been extensively used to compact loose soils to depths of up to 10 m, in order to increase the bearing capacity, decrease post construction settlement and mitigate liquefaction risk in case of seismic events.

Rehabilitation - SM City Marikina Access Road and Bus Bay - South Luzon Expres
way,Rehabilitation - Second Tagus Bridge - Livorno-Civitavecchia Motorway, Lot 1 -
Bosphorus Bridge, Kinali - Sakarya - Gumosova - Gerede Expressway Lot2 - Topkap
Adana Gazientep Expresswey - Tate's Cairn Tunnel Approaches & Prince - Road Ra
Complex Zarate - Brazo Largo - Second State Expressway System NS-3 - Highwa
Benin - Warry Enigma - Third Mainland Bridge 1st and 2nd stages - Udine-Tarvisi
Motorway - Motorway Bridge Mestre-Vittorio Veneto Highway - West Kowloon Recla
mation, Contract WK 22 - E45 Motorway - Second Lot Link Road Lagos - Abeokut
Expressway - Singapore Mass Rapid Transit (Lot 302, Lot 405 A, Lot 102, Lot 20
Lot 402, Lot 618) - Adana-Gaziantep Motorway - Light Railway Transit System, Lin
- Ankara - Istambul Highway - Lecco Link Road - Yacyreta Dam - Service Bridg
Antibo Bridge - City of Naples road network - Puente Sobre el Rio Grande - Ep
Bridge - Livorno-Civitavecchia Motorway, Lot 1 - Railway Caracas-Cua Constructio
Central Artery Tunnel - Torino Bardonecchia Highway, Lot 26 - Puentes San Marco
Cuscatlan - Klong Sip Kao/Kaeng Khoi Railway Project - Second Stage Expresswa
Project - Bangk

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oao Landim Bridge - G.R.A. - SS1 Interchange - LRT Manila Lin
ne-Fiumicino Highway - Salerno-Reggio Calabria Highway - Ugha
on-Omadino Bridge - Bridge over Calabar River - Bridges Saltsj - Bridge Sodertalje
Alger Metro Line 1 - Amburayan Bridge Pier 5 - Maramba Bridge - Amore Bridge - LR
Line 1 North Extension Project - Siam River Bridge - Three Piers of South Metro Manil
Skyway - Transmaghrebian Motorway - High Speed Rail Project, Lot C260 - Viaduc d
Beni Chaib - Viaduc RN11 - Echangeur Est d'Oran, Algerie - Tseung Kwan O Extensio
phase II - Fatala & Tibola Bridges - Khor Al Batah bridge - Al Sowa Island - Roads
Bridges Ras Al Khor Crossing - Skyway Metropolitan Project - Transrhumel Viadut
Bridge over Nokou Lake - Logan 2000, Terminal Area Roadways - Williamsburg Bridg
Reconstruction - Brooklyn Queens Expressway - Bypass over Cape Fear - Railway L
Encrucijada-Puerto Cabello - Brightman Street Bridge at Fall River - Over Missisau
Bay - Railway Bridge on Po River - KCRC West Rail CC-212 - Bomadi River Bridge
Bridge over Rio Limay - Rosario Victoria Phase II - Bridge over Pyandzh River - Que
buza Bridge over Zambesi River - Sao Vicente Bridge - Puente de la Mujer - Nagtahan
Bridge/Flyover Project in Beata - Subic-Clark-Tarlac Expressway Project - Metro Mani
a Project Line 2 - Bridge over Rio Cacheuta - High Speed Railway, Bologne Junction
Forlì Ring Road - Filippella Gallery - KCRC Light Rail Contract CC-230 - Dora Baltea
Bridge - Utor Bridge - Okota-Itire Overhead Link Bridge - Widening of Al Garhoud Brid
e - La Mesa-Magsaysay Aqueduct PNR - New Mabolo bypass Bridge on Bicol River
Gumosa - Gerede Expressway, Lot.1 - Jamal Abdul Nasser Street,RA/167 - Bridge ove
Banio Lagoon - Kassuende Bridge over Zambesi River - Madden/Colon Expresswa

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