PILE DRIVING INSPECTION: GUIDE TO PILING SPECIFICATIONS AND METHODS

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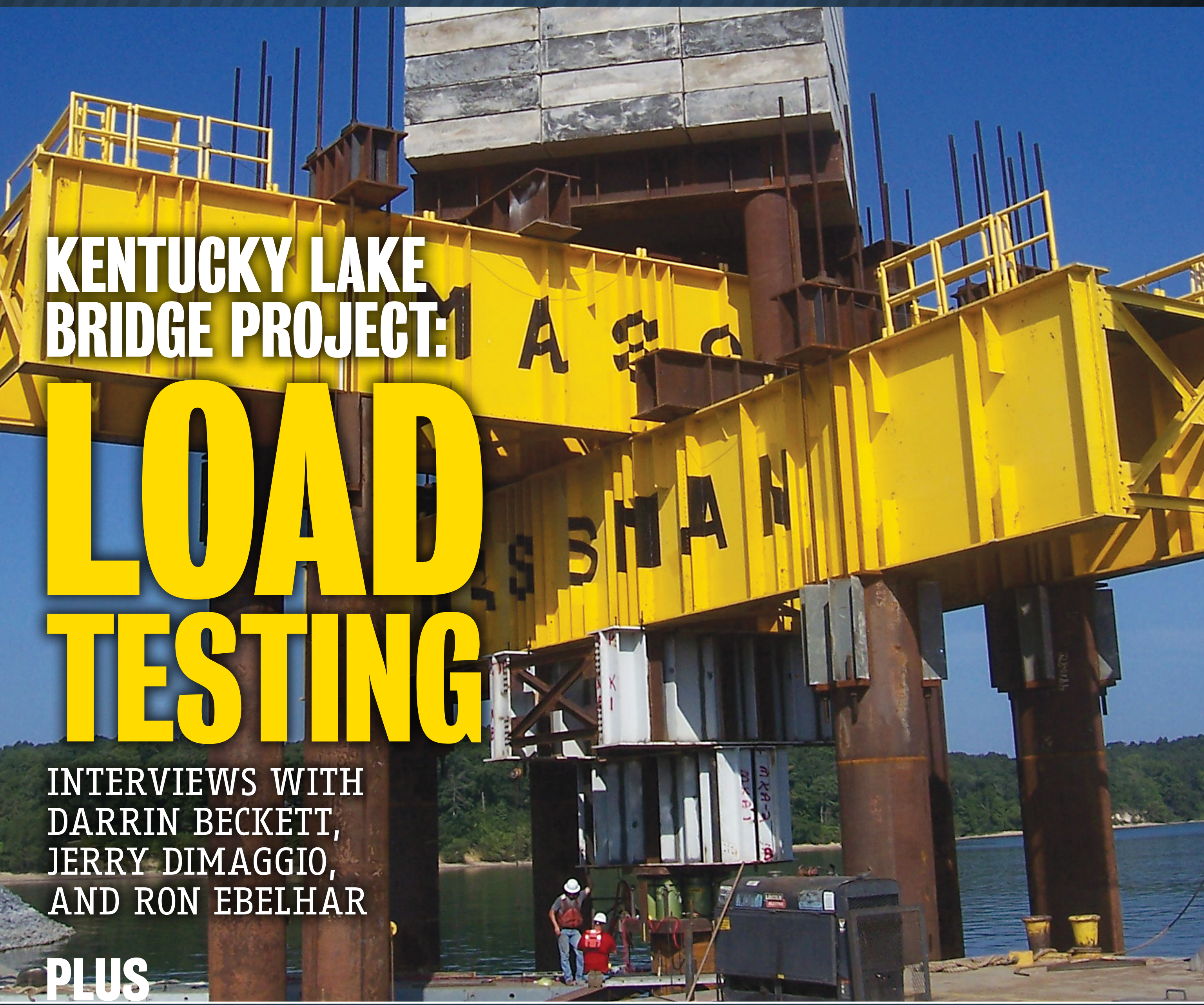

KENTUCKY LAKE BRIDGE PROJECT:

LOAD TESTING

INTERVIEWS WITH DARRIN BECKETT, JERRY DIMAGGIO, AND RON EBELHAR

PLUS

CRANE PILE DRIVING
Who Owns the Loss?

INNOVATIONS IN BRIDGE CONSTRUCTION
Over Bay of Cadiz, Spain

COMMERCIAL DIVING
Offshore Diving vs. Inland Diving

By Jose M. Estanga Casado and Tomas Lester Harding

BRIDGE OF CADIZ

Cadiz, Spain

1. INTRODUCTION

The second bridge over the Bay of Cadiz called "La Pepa Bridge" in commemoration of the Spanish Constitution of 1812 signed in the courts of Cadiz, is one of the most important infrastructure works being carried out in Spain.

It will not only be the longest bridge in Spain and one of the highest in Europe but also the bridge that has presented the most challenges in Spanish engineering and that is demanding the use of the most innovative procedures, machinery and materials with the greatest professionals and technologies in the current market.

2. PROJECT DESCRIPTION

2.1 LOCATION

The bridge with a length of 5km and width of 30m will cross the Bay of Cadiz and linking the town of Puerto Real and the city of Cadiz in southern Spain.

La Pepa Bridge will have a record span distance in Spain and a height of 69m from the sea level.

2.2 STAKEHOLDERS

The Project was commissioned by the MINISTRY OF PUBLIC WORKS AND TRANSPORT of the SPANISH GOVERNMENT to the contractors DRAGADOS, DRACE Y FPS.

The foundation works were awarded to the Spanish companies CIMENTALIA, GEOCISA and TERRATEST, which used the G3 System as fluid stabilizer patented by the company GROUND ENGINEERING OPERATIONS (GEO).

2.3 GEOLOGY

The stratigraphy of the area is strongly influenced by the different geological environments that have affected the zone during its geological history. The excavated soil in the ground phase represent transitions of lagoon sediments and most recently of beach sedimentary environments.

The stratigraphy of the ground phase can be generally described as:

- 4m of typical beach deposits composed of medium-coarse sand.
- 10m of lagoon deposits composed of silt with SPT values below 5. (*Figure 2*)
- 4m of typical deposits between lagoon and beach environments composed of sands interbedded with layers of sludge.
- 15m of lagoon deposits composed of bioclastic rocks with layers of sand.

The excavated soil in the maritime phase, besides representing transitions between lagoon and beach sedimentary environments, also represented deposits from a fluvial environment in the shallow end, which provided layers of gravel. The arrangement of these gravel sized materials are very conditioned by the lateral migrations of stream flows.

The stratigraphy of the maritime phase can be generally described as:

- The depth of the Bay of Cadiz varies from 20m at the deepest to 1m at the shallowest.
- 5m of marine deposits composed of silt with SPT values below 5.
- 5m of fluvial deposits composed of sands interbedded with 2cm size gravels.

Figure 1: Aerial view of the future bridge over the Bay of Cadiz.


Figure 2: Lagoon deposits composed of silt with SPT values below 5, located in both, the first 5 m of the maritime phase and from 5 to 15m in the ground phase.


Figure 3: Batching plant used for the ground operations which has a mixing and storage tanks.

- 20m of deposits that represent transitions between lagoon and beach environments and composed of interbedded bioclastic rocks, sand and clay layers.

2.4 MARITIME AND GROUND PROJECT DESCRIPTION

The Project consists of two phases:

- Ground phase, where two upper accesses to the city of Puerto Real, a viaduct over the neighborhood of Rio San Pedro and an underpass at the entrance of the city of Cadiz, were executed. The foundation works that were executed by companies Cimentalia and Geocisa, had a linear measurement of 6,837m. There were generally 399 piles with a diameter between 1,000mm and 2,000mm and an average depth of 35m.
- Maritime phase, which counts with the execution of a cable-stayed bridge over the Bay of Cadiz with a detachable part. (*Figure 1*) The foundation works were done by the consortium GADIUM, formed by companies GEOCISA and TERRATEST. The surveying of this phase was approximately 5,000 linear meters, and consisted of 106 piles with a diameter of 2,000mm and a depth between 43 and 51m.

All the Project was executed using the G3 System, patented by GEO, as fluid stabilizer.

2.6 SITE LOGISTICS AND MARITIME AND GROUND EQUIPMENT

Due to the rapid hydration of PolyMud, principal polymer of GEO's G3 System, the equipment is reduced when compared to other cast-in-situ pile execution systems. This is one of the advantages that makes the GEO's G3 system an ideal stabilization system for foundations such as floating platforms and in general for any type of construction works as it reduces the transport and space required for mounting the batching plant.

The ground work equipment consisted of:

- A drilling rig.
- An auxiliary crane to move materials and pour concrete in the excavations.
- A recoverable metal casing of 2-3m.
- Drilling tools.
- Tremie pipes for the concrete pour.
- Batching plant (*Figure 3*) comprising:
  - Mixing tank.
  - Storage tanks.
  - Air compressor.
  - Pumps to send and retrieve the slurry.

The amount of this equipment depends on the intended production. The required equipment for maritime works acquires more importance because of the reduced floating platform space.

In this case, the required equipment for maritime works was:

- A boat to transport the materials from land to the floating platform. (*Figure 4*).
- Two tugboats to transport personnel and move the floating platform.
- To pour concrete in the nearshore piles, floating pipes were used and the concrete was pumped from the coast. (*Figure 5*).
- To pour concrete in the offshore piles, a self-propelled floating platform was used which contained 5 concrete trucks. (*Figure 6*).
- A main floating platform, which contained (*Figure 7*):
  - An auxiliary crane.

- A drilling rig.
- A discharge area for materials.
- Storage for drilling tools.
- A vibratory hammer.
- A mixing tank.
- A storage tank for fluid stabilizer placed therein.
- A storage tank for freshwater placed therein.
- Offices, dining room and restroom.

Additionally, the floating platform was designed in such a way that it favored the production, as it had 4 anchors that allowed it to move laterally without the need of tugboats. This way, once the first excavation was completed it moved laterally and started drilling the next pile while the former one was getting the reinforcement rebar cage placed in and during the concrete pour.

Due to the compatibility of the G3 System with the environment, it wasn't necessary to have a boat to transport the excavated material to land.

3. MARITIME AND GROUND WORK PROCEDURES

3.1 MIXING PROCESS AND RECYCLING OF GEO'S G3 SYSTEM

The fluid stabilizer mixing procedure is a fast process which can be done in about 10 minutes. This consists of:

- Correcting the pH level of the water with Caustic Soda to a range between 11-12.
- Recirculating the water and adding compressed air inside the tank so the mixing is the most homogeneous possible.
- Applying granular PolyMud to the water jet.
- Wait 10 minutes to ensure homogeneity and send it to the storage tank.

Once the fluid stabilizer is manufactured it is sent to the excavation as it progresses. When the excavation is completed, a decantation chemical is applied using the procedure shown in *Figure 8* and the excavation should be ready for the concrete pour. While the concrete is sent through the tremie pipe, because of the difference in the specific weight, the slurry ascends and it's retrieved to the tanks where the parameters would be corrected if required and the slurry would be set for the next excavation. This way, the fluid stabilizer is recycled

Figure 4: Auxiliary boat to transport materials from the coast to the floating platform. This boat also provided fresh water for slurry mixing, casings for the piles and reinforcement rebars. Other operations included tugging and transporting personnel from land to the platform and vice versa.

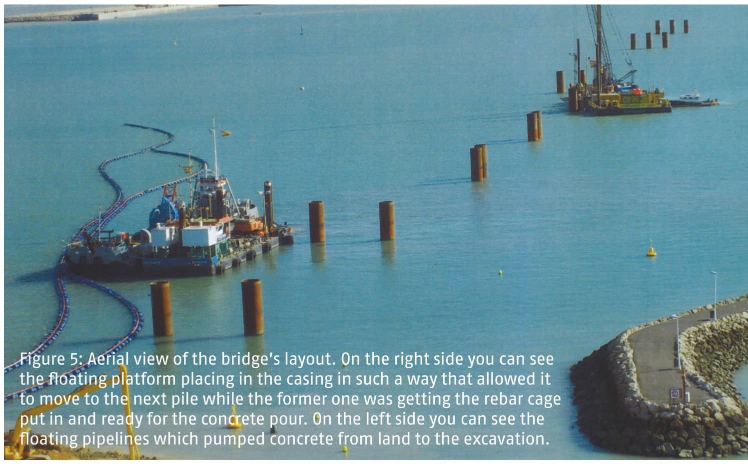

Figure 5: Aerial view of the bridge's layout. On the right side you can see the floating platform placing in the casing in such a way that allowed it to move to the next pile while the former one was getting the rebar cage put in and ready for the concrete pour. On the left side you can see the floating pipelines which pumped concrete from land to the excavation.

reducing the consumption of the product. The remaining procedures slightly differ between maritime and ground works.

3.2 GROUND WORKS

The piling execution process in ground works begins with placing a recoverable casing of 2-3m. As previously indicated, fluid stabilizer is applied during the excavation process which was mixed in the batching plant following the steps in 3.1. When drilling is completed, the slurry parameters are monitored and ensured they are in the recommended values. If not, chemical decanting would take place, as described in *Figure 8*, the pile toe would be cleaned and the reinforcement rebar cage

Figure 8: Chemical cleaning procedure:
1. Put diluted MicroBond in a bag with a stone.
2. Throw the bag in the excavation and wait until the bag reaches the bottom.
3. Descend with the drilling tool to the bottom of the excavation.
4. Burst the bag with the drilling tool turning it counterclockwise.
5. Stir the slurry with the drilling tool in the last 2 meters of the excavation.
6. Allow the slurry to decant about 15 minutes and clean the bottom of the excavation.

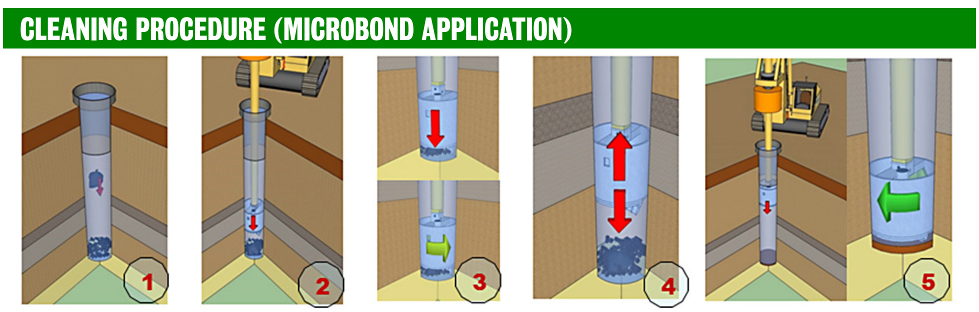

Figure 6: Self-Propelled floating platform loaded with concrete trucks for concreting the farthest offshore piles. It also served to transport materials to the platform, like in this case, the rebar cage for the next drilled excavation.

Figure 7: Equipment layout on the working platform.

would be installed. After the installation of the cage, it would follow with placing the tremie pipe and finally the concrete pour. Following the recycling of the G3 System, because of the difference in specific weight of the concrete and slurry, the later will be retrieved to the tanks and ready for the next pile. After completing all piles from a single pier, the pile cap is formed by doing an excavation of approximately 2m in depth.

3.2 MARITIME WORKS

As quoted above, maritime works slightly differ from ground works. The procedure begins placing a casing with a length exceeding 5 m from the water level when high tide. (*Figure 9*) From this casing, the part that exclusively corresponded to the depth of the bay was recovered, leaving 4m of the casing in the ground. In order to increase the production, all the casings that were within the same axis were placed at once. Once the casings were placed, the salt water within the casings was treated which depended on the depth of the sea level at that moment. The treatment consisted of applying 3 liters of Caustic Soda per cubic meter of salt water. The next step to start the excavation, and the same happens with the ground works, is to introduce the slurry while the excavation progresses, keeping it always 1m above the sea level. When the excavation was completed, the parameters of the slurry were checked to be in the recommended values and then the platform would move laterally by means of anchors as described in section 2.6. to the new excavation while the first one was getting the rebar cage installed.

Because the Bay of Cadiz has a tidal race up to 6m, a platform was designed that hanged from the casing so the labors could work safely while they put in the cage.

Once the reinforcement rebars were overlapped and placed in the excavation, the tremie pipe was introduced and the concrete pour began.

Fort the nearshore piles, the concrete pour was done by floating pipelines that pumped concrete from land. (*Figure 5*). Fort the offshore piles, the concrete pour was done with a second self-propelled floating platform that carried 5 trucks that pumped concrete to the excavation. (*Figure 6*).

Following the recycling of the G3 System, the slurry was retrieved and used for the next excavation.

3.3 CHALLENGES

A work with these characteristics involves numerous challenges. In the execution of some piles, it was necessary to interrupt one of the two entrances to the city of Cadiz, which resulted in doing all the operations during the night, both excavation and the concrete pour, and because there were heavy vehicles circulating on site it wasn't possible to leave the excavation open during the day. Thanks to the high speed cleaning process that the G3 systems offers, this aspect did not present any problem and did not cause any harm to Cadiz's population.

Maritime works always generate unexpected situations and uncontrollable by humans, like storms and the rise and fall of tides.

The rise and fall of tides mainly affect the supply of materials to the floating platforms and therefore the production. One of the factors that might have affected the production was not having fresh water for mixing. However, it was possible to mix with salt water without stopping production thanks to the ability of the G3 System.

Figure 9: Moment when the casing was being placed and driven in by a vibratory hammer.

The storms also affected the work, because the initial objective of using floating pipelines for the concrete pour, when there was a storm, resulted in them to break apart and their repair was hard to achieve.

This forced to keep one pile open for 3 months while the floating platform was being mounted with concrete trucks. Thanks to the reliability of the G3 System, the pile left open for 3 months remained stable and there was no difference in the depth, making it possible to pour concrete without additional drilling.

4. ADVANTAGES AND ACHIEVEMENTS

Due to the characteristics of the G3 System, environmental, reduced equipment, fast cleaning and reliability in soil stabilization, its selection as fluid stabilizer contributed to:

- Execution of piles overnight without causing traffic problems to the population of Cadiz.
- Reduction in the number of floating platforms for the maritime works.
- Reliability in stabilizing the excavations in unexpected situations and achieving the required conditions for the pour concrete.
- Maximum production achieved in the maritime phase of 8 piles of 2,000mm and 50m in depth in a period of 6 days.
- Minimal environmental impact.

5. ENVIRONMENT

In maritime works, it's important to take care of the seabed and its environment, since there are numerous living beings involved. The G3 System and its tested compatibility with the environment didn't cause any impact to the wildlife, resulting in a very effective working system in construction without harming the environment.

6. CONCLUSION

The bridge over the Bay of Cadiz has been a project of great importance which has not only tested the potential of Spanish engineering but also the products and techniques used when executing such large projects. GEO's G3 System with onsite technical assistance provided numerous solutions and advantages that allowed great progresses in the execution of foundations, in both ground and maritime situations. ■