La Taboada (Lima-Peru) outfall

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Keywords

La Taboada, outfall, construction, PE, pipes, design

Introduction

As we explained in previous MWWD Congresses, in recent years, we have been involved in the design and construction of the pipelines for several marine projects, as sewage outfalls, desalination plants, marine farms and seawater cooling circuits. Most of these projects have been constructed with helicoidally welded PE pipes, which were manufactured by the Spanish company PPA&KRAH. This Company also executes marine works, such as dredging, ballasting or sinking of the pipe.

Now, we face a new challenge: the construction of La Taboada outfall, in the city of Lima (Peru).

The history

When Isidro Sierra, general manager of PPA&KRAH, called me seven years ago, asking for my cooperation in the design of pipes, joints, sinking methods and all the aspects that are needed for the installation of large diameter PE pipes on the sea, we couldn't imagine the large development and the wide extension of the use of their pipes for all kind of marine installation.

I had been involved in the design and construction of PE outfalls since 1996 but the use of PPA&KRAH pipes meant a new challenge, as their diameter is huge. This extraordinary size (reaching 3 m of internal diameter in La Taboada outfall) obliges to very accurate calculations and a complex set of marine equipment.

Taboada outfall

- The site

Taboada outfall is placed in the city of Lima (Peru), just beside its International Airport "Jorge Chavez". The island of San Lorenzo protects it against the waves coming from the South (which is the main direction of the storms).

- The contract

These works are constructed for the "Ministerio de Vivienda, Construccion y Saneamiento" (Ministry of housing, construction and sewage); from the Government of Peru.

The main contractor is ACS, which will be responsible for its construction and operation. Increa did the project which was the base of the technical offer of ACS and, after getting the contract, Increa has been in charge of designing all the details.

PPA&KRAH has been awarded (by ACS) with the supply and installation of the pipe, apart from different marine works.

- Project description

This sewage outfall has a total length (including a short length onshore) of 3900 m and reaches a sea depth of 13 m in the Pacific Ocean. The internal diameter of the pipe is 3 m, made of HDPE, helicoidally welded.

The diffuser has 1000 m and its internal diameter gets reduced along it in order to increase water speed inside it. This is why only the first 340 m have an internal diameter of 3 m. The following 330 m have 2,4 m of diameter and the last 330 m have 1,8 m.

Concrete blocks are placed around the pipe, with the following distribution:

- Onshore string: one block of 13,5 t every 11,6 m.
- Offshore string, before the diffuser: one block of 13,5 t every 5,8 m.
- First 340 m of diffuser (3 m of internal diameter): one block of 9,7 t every 4 m.
- Next 330 m of diffuser (2,4 m of internal diameter): one block of 6,5 t every 4 m.
- Last 340 m of diffuser (1,8 m of internal diameter): one block of 4,2 t every 4 m.

The pipe will be placed in a trench that should be dredged at the seabed. The material to be dredged is mud and this fact has affected the design. The depth of the trench will allow the pipe to have enough cover over the pipe, so that changes in seabed profile due to storm never uncover the pipe.

The pipes are equipped with manholes and air-valves.

The diffuser string is protected against fishing nets and crawlers by placing concrete blocks with metallic profiles on the seabed.

A buoy will mark the end of the outfall, in order to prevent accidents caused by ships.

Seismic hazard has been taken into account: PE is the most appropriate material, as it is very flexible and joint withstand longitudinal forces.

- **Environmental Outfall Design**

An environmental optimization has been carried out. In this sense, an optimization of the length of the outfall and the diffusers design has been defined after a numerical modelling analysis. A set of numerical experiments were designed based on a deep analysis of the environmental conditions of the region. Meteo-oceanographic conditions were evaluated as far as possible with the available data. This analysis revealed the main hydrodynamic conditions, influenced basically by the Humboldt Current in the sea-boundary of the Callao bay, and a persistent south wind component.

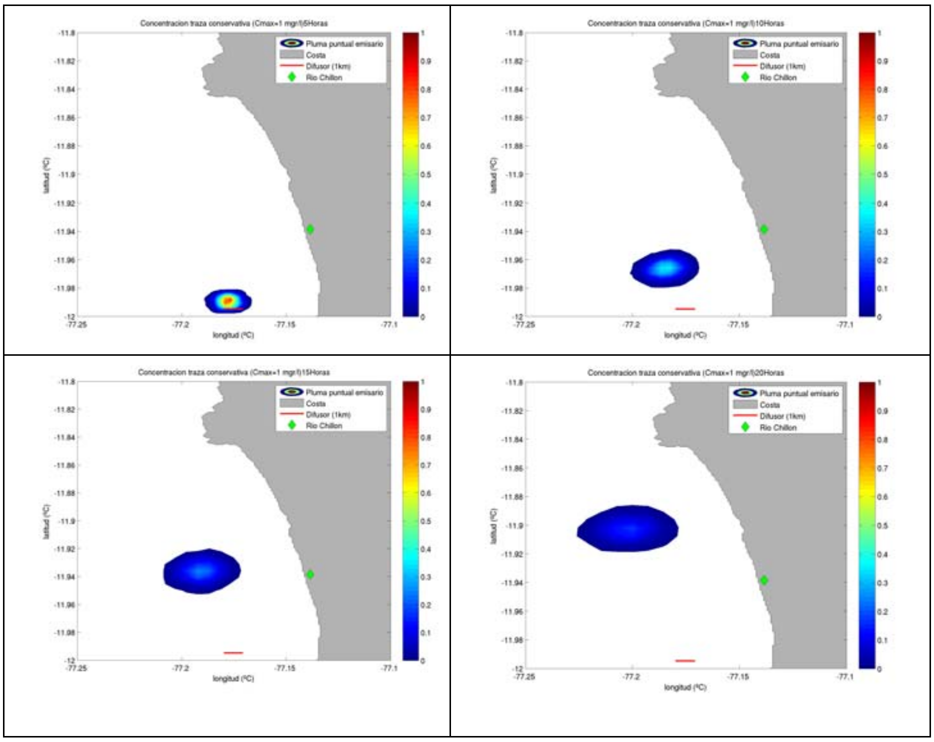

Figure 1 Temporal evolution of a conservative tracer in La Taboada outfall.

The mixing zone model CORMIX (Cornell Mixing) has been coupled with a far-field implementation of conservative/non-conservative tracer given by ROMS (Regional Ocean Modelling System). As a first step, the coupling system has allowed to determine the minimum distance of the outfall in order to accomplish the regional water quality standards (total offshore length of 3.5 km). Complementary, the initial dilution has been maximized according the diffusers distribution (250 risers, placed every 4 m, with two ports on each one). Several substances have been simulated according the current peruvian legislation, which limits the concentration of pollutants at the coast. The figure 1 shows the temporal evolution of a conservative tracer used to design La Taboada outfall from an environmental point of view.

Other previous projects

La Taboada project is becoming a reality thanks to the large experience we gained in previous projects. The success of these projects (developed with large diameter pipes, reaching 2400 mm of internal diameter) and the experience we got, enable us to face Taboada Outfall with confidence and enthusiasm.

During these projects we have been solving different issues and we have much learnt about the behavior of PE, mainly during its construction, transport and installation.

This is why we want to explain, briefly, these projects, which are (most of them) completely finished, laying under the sea. During the oral presentation, many pictures will help to understand them.

- **Rain water outfalls for the city of Cadiz (Spain).**

This Project has 3 pipes with 3 different diameters. Each pipe is placed in a different zone of the city, draining rain water, from the streets to the sea. The first one, called “Paz Puntales”, has an inner diameter of 1800 mm and 739 m in length.

The second one, “Cortadura” has an inner diameter of 800 mm with a length of 301 m. The third, “Santa María del Mar”, has an inner diameter of 1400 mm with a length of 220 m.

Figure 2. Cadiz outfall of 1800 mm, during sinking

- **Water Cooling System (outfall) for Power Station in Sagunto (Spain).** (see previous Congresses)

The outfall has a diameter of 1.800 mm and 405,2 m in length.

- **Water Cooling System (intake and outfall) for Power Station in Algeciras Bay (Spain)**.

There are two intake pipelines of 2.400 mm and 350 m in length each. The intake towers are located at -15 m
There is an outfall pipeline with an inner diameter of 2.400 mm and 800 m in length. The outfall has a diffuser system at the depth of 36 m

Figure 3 Algeciras outfall (diffuser zone), during ballasting

- **Water Cooling System (intake) for Chemical Plant of Fertial in Arzew (Algeria).**

The intake pipeline has an inner diameter of 2.400 mm and is 466 m long.

Figure 4 Arzew plan view

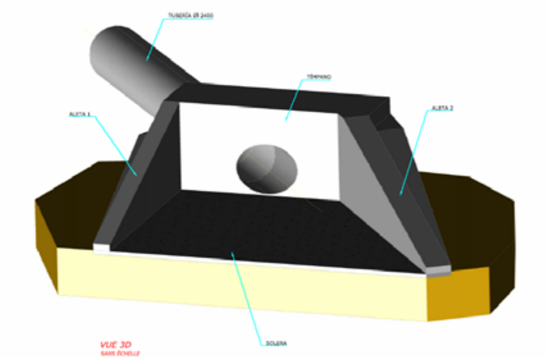

Figure 5: Detail of the connection between the pipe and the onshore channel

- **Water Cooling System (intake) for Power Station in Koudiet (Algeria)**.

The seawater intake is designed with 4 pipelines in parallel. The inner diameter was 2.400 mm and they were 487 m long.

Figure 6 Works on land at Koudiet.

- **Water intake and outfall for the following desalination plants**:
    - **Valdelentisco- Murcia (Spain).** (see previous conference)
    - Intake pipeline: DN 1.800, length 1.105 m. Maximum depth of 26 m.
    - Outfall: DN 1.500 mm, length 1.260 m, depth 22,5 m.

Figure 7 : Valdelentisco intake pipe, floating before submersion

- **Skikda (Algeria).** (see previous conference)
- Intake pipeline: Inner diameter 1.800 mm, length: 1.171 m, maximum depth 18 m
- Outfall pipeline: Inner diameter 1.500 mm, length: 676 m, depthd maximum 9 m

Figure 8 Skikda: pipes during launching at the port

- **Beni-Saf (Algeria):** (see previous conference)
- Intake pipeline: Inner diameter 2.400 mm, length 1.200 m
- Outfall pipeline: Inner diameter 1.800 mm, length 1.574 m (long part of them, onshore)

- **Honaine (Algeria):**
- Intake pipeline: Inner diameter 2.400 mm, length 900 m.

- Outfall pipeline: Inner diameter 1.500 mm, length 460 m.

- **Mostaganem (Algeria).**
- Two Intake pipelines: Inner diameter, DN 1.800; length: 2.435 and 2.535 m. Depth: 16 y 16,5 m
- Outfall: Inner diameter 1.800 mm; length 1540 m; depth 9,5 m

Figure 9 Mostaganem: pipes floating in a trench excavated at the beach, before transport and sinking

- **Cap Djinet (Algeria).**
- Intake pipeline: Inner diameter 1800 mm, length 1.779 m
- Outfall pipeline: Inner diameter 1.200 mm, length 1.170 m

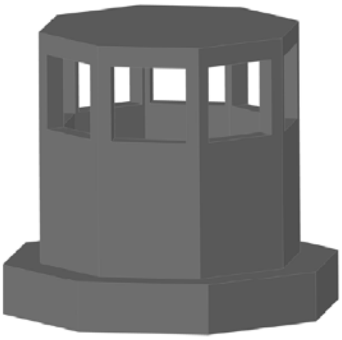

Figure 10 Cap Djinet: intake tower.

- **Water intake for desalination plant of Aguilas (Spain).**
  - Intake pipeline: Inner diameter, 2.200 mm; length, 509 m; depth 17,6 m.

Figure 11 Aguilas: the pipe, during launching at the shore.

Lessons we learnt

The main lessons we have learnt during the design and execution of these projects, are:

- PE pipes are the best solution for marine pipes. When large diameters are needed, helicoidally welded pipes (conveniently designed) are the only possibility we have with that material.
- Installation of the pipe on the seabed should be deeply studied by engineers with large experience in both calculation and marine construction aspects.
- As installation is very often the worst situation for the pipe along its whole life, it should be optimized in order to reduce what is imposed to the pipe characteristics (wall thickness, inertia, etc).
- The best method for installation of PE pipelines of medium or small diameters (<1500 mm) to the sea floor (depths up to 30 m), is the method of "controlled sinking by progressive flooding" of the pipeline.
- Nevertheless, when diameters or depths are larger, the use of floaters for installation is highly recommended.
- Ramps on land should be carefully studied for large diameters, as angles on them can impose too high stresses on the pipe and huge forces on the ramp.
- Marine works are highly dependant on sea conditions. Weather forecasts should be precise and they should be available well in advance.
- A generous fleet is need during sinking. Though its daily cost can be high, as these operations are short, it worths its price.
- Placing the pipe in a trench is the best protection we can give to it. We recommend designing a deep trench, in order to get a big cover over the pipe. In this case, it is enough to fill the trench with the same material which was dredged. If not, concreting the trench or filling it with coarse material is a good protection against sea and accidental actions.

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