PE PIPES FOR SEA OUTFALLS AND WATER INTAKES: A COMPARISON BETWEEN SOLID WALL AND HELICOIDALLY WELDED PIPES

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INTRODUCTION

Discharged fluids into the sea (sewage, for example) are quite common. There are also many coastal facilities that must take water in and later evacuate the effluent so they can operate: desalination plants, gas turbine power plant, fish farms, etc.

The material most often used for these pipelines is high density polyethylene (HDPE or PE).

The type traditionally used is **massive wall**, in which the pipe is formed by a circular and solid wall of HDPE.

The problem of these pipes is that maximum thicknesses is limited, due to the production technology (making pipes thicker that 100 mm gets complicated). This fact means a maximum diameter of around 2,000 mm.

In order to solve this problem, some companies have developed structured **pipes** which are **helicoidally welded.** They achieve greater transversal strength with less material and enable the execution of pipes with a diameter of up to 4,000 mm.

PRODUCTION

Massive pipe is created by means of continuous extrusion. The HDPE is inserted in grains into the extrusion machine and once inside, a propeller pushes the melted material through the head and distributes the mass to the nozzle where the pipe will take on the desired diameter and thickness.

Helicoidally welded structured pipe is produced by combining the extrusion head transfer movement with the mould rotation movement which generates propelled material that covers the mould surface. In other cases, a tubular element is curved and helicoidally welded to create the pipe without the need for a mould.

THE CHOICE OF PE AS THE RIGHT MATERIAL

When choosing what material is the best for a marine outfall or water intake on the sea, it is important to take into account many aspects besides the simple cost of the pipe supply.

When **working on land,** installation of pipes (and excavating and filling the trench) is quite simple and cheap.

But when **working at the sea,** all these aspects related to construction become more complicated and means the largest part of the budget for the job. There are many activities to do: dredging a trench, regularizing it, placing the pipe inside, making joints, protecting the pipe and other complementary activities. The use of divers is expensive and it should be reduced to a minimum, especially at big depths.

Figure 1: Desalination plant of Beni Saf (Algeria). Helicoidally welded pipes of 2400 mm, produced by PPA&KRAH

We should take into account that most marine outfalls are placed in open areas, where there is no protection from the sea (waves and currents). Its construction is not a port and harbour issue. Depending on the area and the period of the year, the time when marine equipments can work is much reduced. For instance, in Europe, marine construction activities are stopped in winter. Even in summer, working in the Atlantic Coast should be restrained to only few weeks.

This is why PE pipes are the best solution for marine outfalls. Apart from construction aspects, PE has other advantages:

- Its high resistance to corrosion, making it ideal in an environment as aggressive as it is sea water.
- Its low surface roughness, which improves the hydraulic behaviour, achieving higher hydraulic capacities.
- Reduced adhesion of living beings on its surface, which improves the hydraulic behaviour in the long term and reduce other problems associated with the proliferation of organisms on their surface.
- Excellent performance against the actions of the sea, by its great flexibility, allowing it to adapt to resist their forces, through its deformation without deteriorating.
- Their earthquake behaviour is unbeatable (it could support problems of liquefaction of the ground).

On the other hand, it has some disadvantages: the main one is its density, less than 1 t/m3, forcing the use of concrete ballasts that make the pipeline stable at the bottom of the sea, after its sinking.

Another aspect with which special care should be taken is the lack of robustness of PE against accidental actions (with "cutter" effect), such as cables and fishing gear. Therefore, it is recommended to cover the pipe with some element of protection, in any case.

CHARACTERISTICS OF BOTH TYPES

Both types are compared below:

Mechanical characteristics: Spring welded pipes are more transversal-resistant with the same materials, due to the lighter profile.

Production: Structured pipe is produced in tubes with a length that is equal to the mould used (about 6 m). Massive pipes can be produced in any length desired (more than 500 m); however, they are often cut into 12 m sections for transport.

Transport: If the manufacturer is situated near a navigable zone, the massive solution can be towed in the full length from the plant to the worksite, meaning 500 m sections can be accepted.

Section Assembly and Storage: In both cases, a site is needed to install the ballast weights and prepare the sections for sinking. The joints must be carefully analysed, especially in the case of helicoidally welded pipes.

Installation: the construction method most often used is controlled sinking by progressive flooding of the pipe. In the case of large diameters, sinking is done with the help of floaters to reduce the stresses and for easier manoeuvring. As the wall of structured pipes is optimized the use of floaters will allow a great reduction of their section. As this aspect is very important, we will explain it in detail, below.

Figure 2: Sewage outfall of Berria (Spain). Solid wall pipe of 1600 mm.

INSTALLATION TECHNIQUES

Introduction

The sinking of PE pipelines in the sea is a complicated operation whose risks increase with its diameter. The traditional system of controlled sinking by progressive flooding of the pipe, which we have applied in many projects, should be replaced by others if the pipe diameter is over 1600 mm because it is more difficult to control the pipe and to implement any methodology to decrease stresses.

Traditional sinking methodology

Traditionally, for the installation of PE pipelines of medium or small diameters (<1500 mm) on the sea floor, the method of "controlled sinking by progressive flooding" of the pipeline is used. This method can be executed without difficulty for these diameters in shallow water (depth<30 m), always when the forces generated in the pipeline throughout all of the phases are analyzed with great detail.

- Sinking Phases:

Phase 1) Pipe floating on the surface: the pipe is empty and remains straight, with no efforts, except for those due to the axial force created by the horizontal pull (due to towing).

Phase 2) Water is placed inside the end of the pipe, which makes it start sinking. Air will be gradually released on the other end. The pipe behaves like a cantilever where the filled end is loaded downwards and the rest upwards. The most unfavourable moment in this phase happens just before reaching the bottom. At the opposite end, the water valve must be completely open.

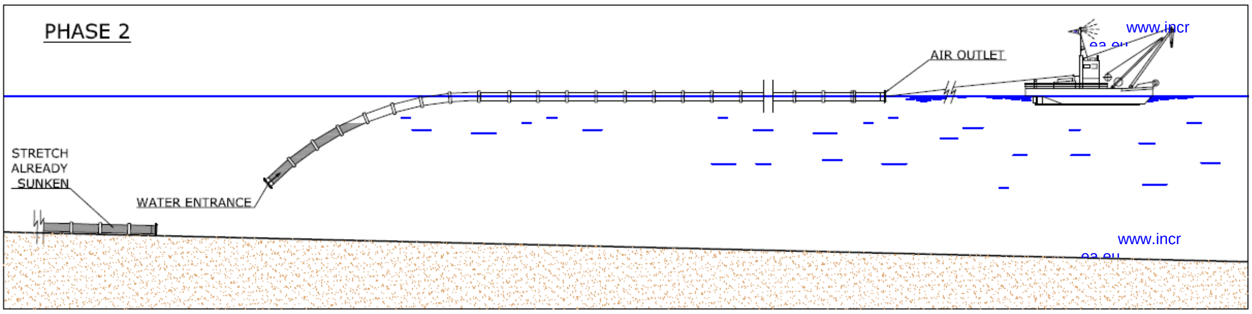

Figure 3: The sinking process start. Water is coming in from one extreme and air is going out from the other

Phase 3) When the amount of water inside the pipe is enough, its end touches the seabed. When the quantity of water inside the pipe increases, the angle between the pipe end and the seabed gets reduced.

Phase 4) As the flooded length increases, a moment arrives in which the pipe rests longitudinally on the bottom. Increasing the quantity of water inside the pipe, the length resting on the bottom becomes bigger, meaning that the "S" that forms between it and the surface of the sea moves. The shape of this "S" and the height to which the water in the pipe reaches remains constant, only suffering horizontal movement.

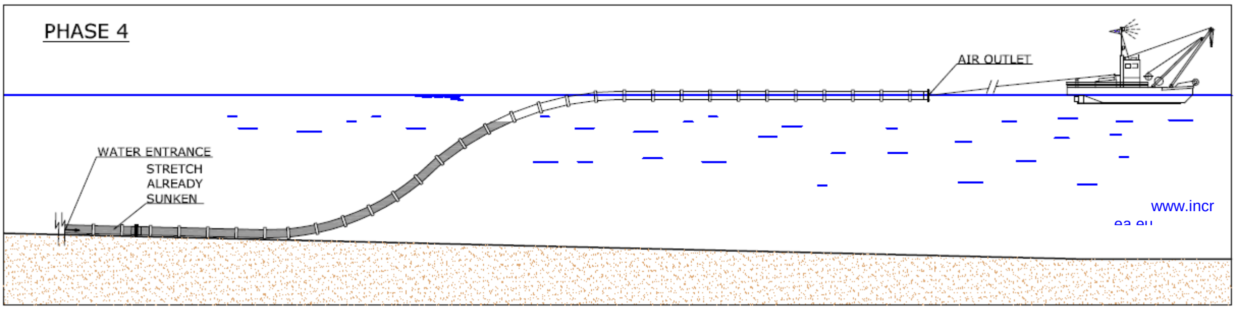

Figure 4: Pipe gets the slope of the bottom. The joint is done

It is during this phase when the new section starts to be joined to that located on the seabed. For stopping the movement of the S, to make the joint, it is necessary to close the exit of air at the end that is floating

Phase 5) Pipe under the surface of the sea: as water enters the pipe, the length seen on the surface reduces until the pipe leaves the surface entirely. Due to part of it is still full of air, the pipe presents a certain length above the seabed. If the pipe were very rigid, the end could even show above the surface.
The pipe behaves like a cantilever, with its loaded end towards the top and the part close to the bottom loaded downwards.

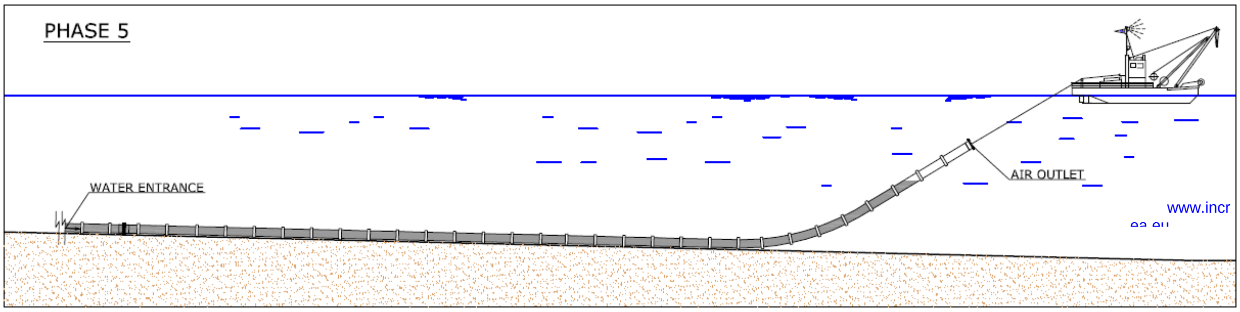

Figure 5: Pipe under the surface of the sea. Water is coming in from one extreme and air is going out from the other

Phase 6) Pipe on the seabed: when no air is left inside the pipe, this completely rests on the seabed, and no effort is seen, other than that due to possible curvatures of the seabed.

Innovative sinking methodology
Sinking pipes of large diameter with the traditional methodology is too complicated. This is why we have developed new procedures that reduces stresses in the pipes and lead to the optimization of the geometry of the tube and thus minimize the cost of the job.
It also simplifies the process, especially when executing joints on the sea bed.
Using flotation devices to help the sinking of these types of pipelines solves many of these problems without the need for extreme means of construction.
Having greater margin of safety facilitates the maritime operations, minimizing risks and making simpler management of the operations possible.

This method makes the need to apply longitudinal tension forces to the tube unnecessary, which simplifies the process of pipeline installation, especially when executing joints on the sea floor.

- Sinking Phases:

This section describes the two-stage sinking method with flotation devices.

These flotation devices can be rigid or flexible.

During the transport of the section of pipes, floating on the sea, it is essential not to force the position of the pipeline in order not to produce excessive tensions.

In addition, it is indispensable to prepare a launching slope for the introduction of the pipes in the sea, from the land area where they are welded and ballasted.

Over this launch slope we will weld the pipes and place the ballasts. The profile should also be carefully studied, as bending of the pipe should also be controlled during launching.

The sinking process with the help of flotation devices is realized in two different stages, which are explained in the following sections.

First Stage:

The first stage consists in the complete and progressive flooding of the pipe while it hangs by the flotation devices (which stay on the surface of the water). At the beginning of the flooding process (and consequently the sinking of the pipeline), the cables and the flotation devices begin to work, pulling up on the pipeline from the surface of the sea. The forces produced in this stage will be as smaller as the shorter the cable length is. At the end of this stage, once the pipeline is completely full of water, it remains in a horizontal position, completely suspended by the flotation devices.

This first stage would the equivalent of what has been traditionally done with lower diameter pipes, but at the depth marked by the slings. Calculations have to take into account the progressive pipe filling process and the variable push load of the flotation devices as they sink. In general, the flotation devices on this end fully sink in the beginning and during the initial pitch phase.

Below we will explain in detail this procedure, dividing this first stage into the following phases.

Phase 1. – The pipeline is floating on the water surface, full of air. The connection between the pipeline and the flotation devices is done by slings, although they are not yet working.

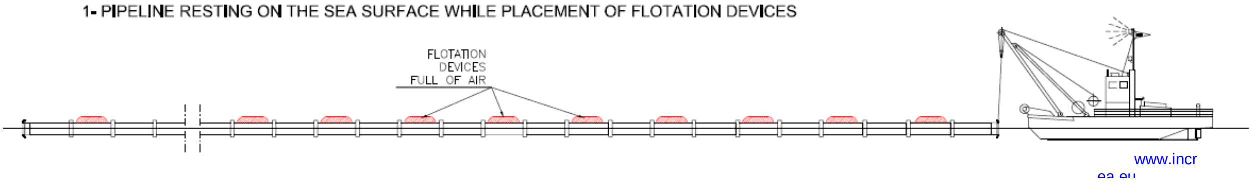

Figure 6: **Phase 1, Pipeline resting on the sea surface while placement of flotation devices**

Phase 2. – The pipeline is flooded by opening the water valves at one end and the air valves at the other. When the amount of water inside the tube is sufficient, the first flotation device will begin to sink, generating a vertical reaction.

The water valves should never be opened at both ends because it would generate an air bubble in the centre of the tube which is difficult to expel.

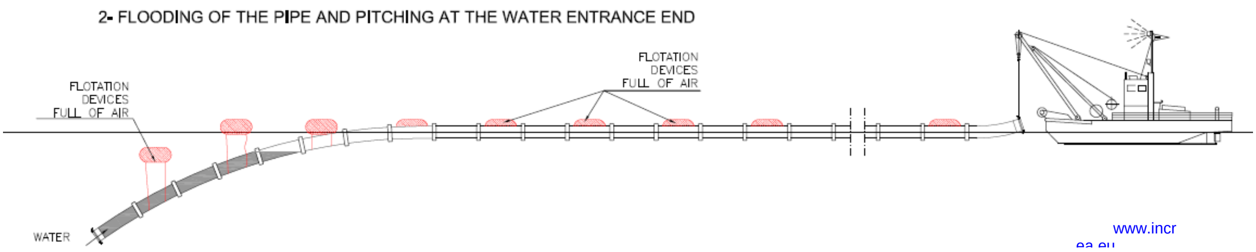

Figure 7: **Phase 2, Flooding of the pipe and pitching at the water entrance end**

The tube acts as a cantilever in the way that one end is loaded downwards, and the rest loaded upwards.

Phase 3. –The pipe appears horizontal in the initial zone, forming the classic "S" shape and advancing in a way which augments the length of the flooded pipe. The "S" shape and the height stay constant, resulting in only a horizontal displacement.

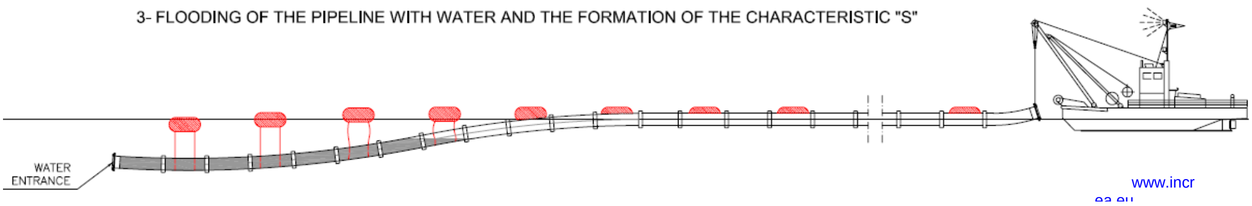

Figure 8: **Phase 3, Flooding of the pipeline with water and the formation of the characteristic "S"**

Phase 4. – As water continues to enter the pipe, the length visible on the sea surface reduces until the entire pipe is no longer visible. The pipe acts as a cantilever with one end loaded upwards and the end closer to the sea bottom loaded downwards.

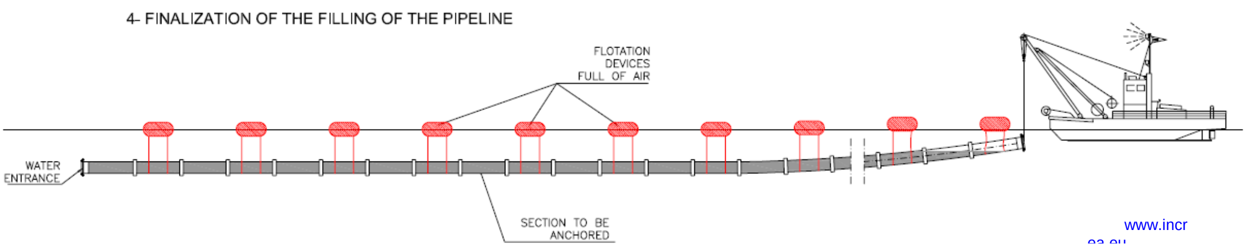

Figure 9: **Phase 4, Last stage of the filling of the pipeline**

Phase 5. – At the end of the flooding process, the tube hangs from the flotation devices, with a straight form, resting a few meters below the surface.

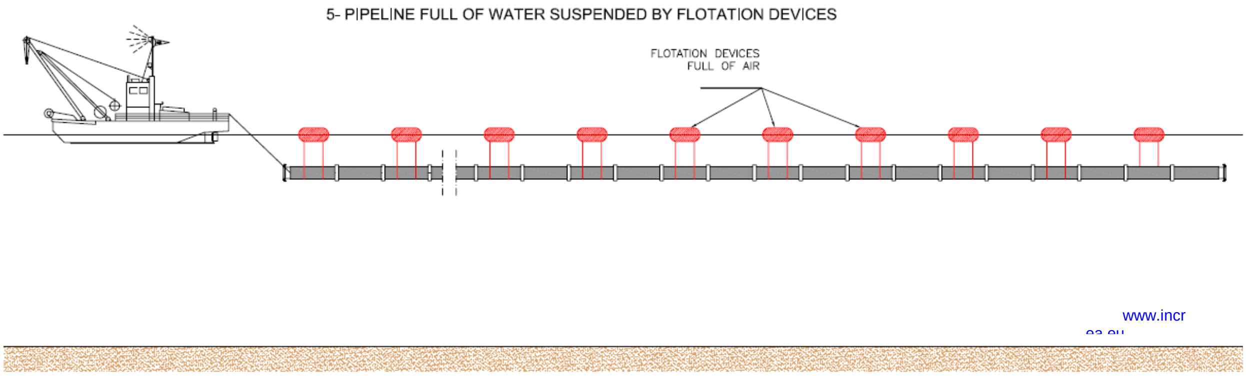

Figure 10: **Phase 5, Pipeline full of water suspended by flotation devices**

This is the moment to verify that the residual floatability is what was expected and that all the flotation devices are working perfectly. In the case of having to use precautionary flotation devices and after checking they are not necessary, they should be removed before starting the next stage.

Second Stage

Once the pipeline is in a horizontal position and straight, it passes into the second stage, which consists in the progressive flooding of the flotation devices, starting at one end and continuing along the pipeline until the entire tube rests on the sea floor.

During sinking, one area of the pipe (the lowest) is no longer being pulled by the flotation devices (as they have been flooded), the flotation devices are already submerged in another area, with their maximum buoyancy, and, in yet another area, the flotation devices are submerged halfway with a variable buoyancy force. These facts must be taken into account in order to calculate this process.

In this description, we will discuss the flooding of the flotation devices, or the exhaustion of them, referring to the same phenomenon, by which the said flotation devices lose their lifting capability, or floatability. If the flotation devices were rigid, in reality they will be flooded. If they are flexible, they will empty themselves of air, or in other words, proceed until their exhaustion.

Since, in this stage, the flotation devices are going to descend to a greater depth, it is important, in the case of flexible flotation devices (balloons or similar) to maintain their volume as they descend to the sea floor. To do so, they should be duly pressurized.

Phase 1 (of second stage). - Corresponds to the last phase in the first stage. The pipeline remains straight, hanging from the flotation devices, a certain distance from the surface, and most importantly, without forces, except for those due to the discontinuity of weights (ballasts) and lift force (flotation devices). The valves for the entrance of water to the tube should be open so that the internal and external pressure of the water are equal.

Phase 2. –The second phase of the process begins: when the first flotation device is flooded, the pipeline begins to descend towards the sea bottom from that end, while the other end remains at the depth marked by the length of the slings. As the flotation devices continue to be flooded, the pipeline end increases its depth.

The flotation devices on the surface of the water (even those full of air) begin to sink and disappear from the sea surface. So the diver is always executing the operation of emptying out the devices at a certain depth.

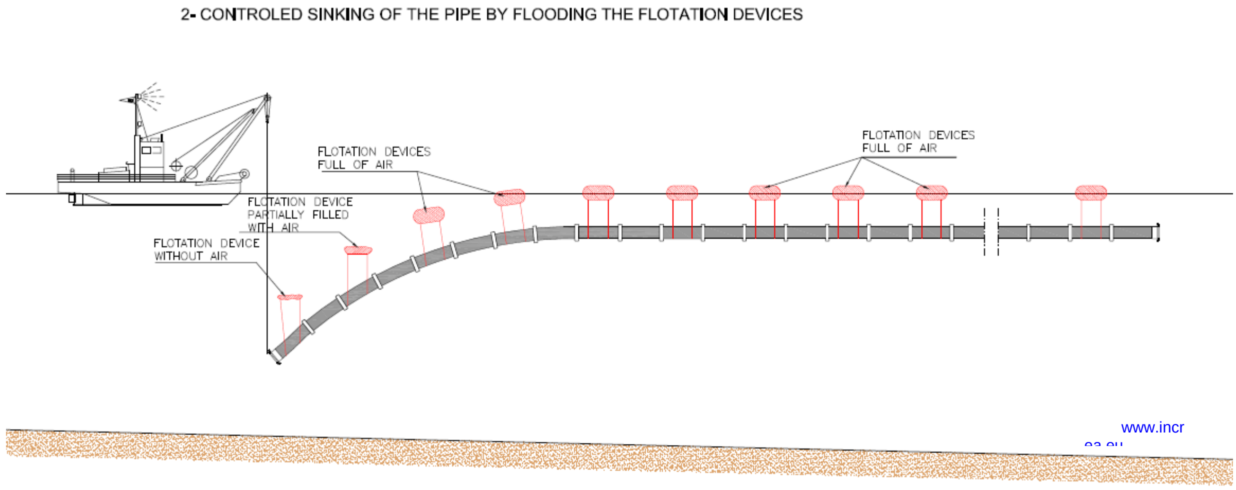

Figure 11: Phase 2, Controlled sinking of the pipe by flooding the flotation devices

Phase 3. – When a sufficient number of devices have been flooded, one extreme of the pipeline touches the bottom of the sea. In the case of flexible flotation devices, the individual and progressive flooding of each device is necessary, so that the sinking is controlled with ease and is not unnecessarily accelerated.

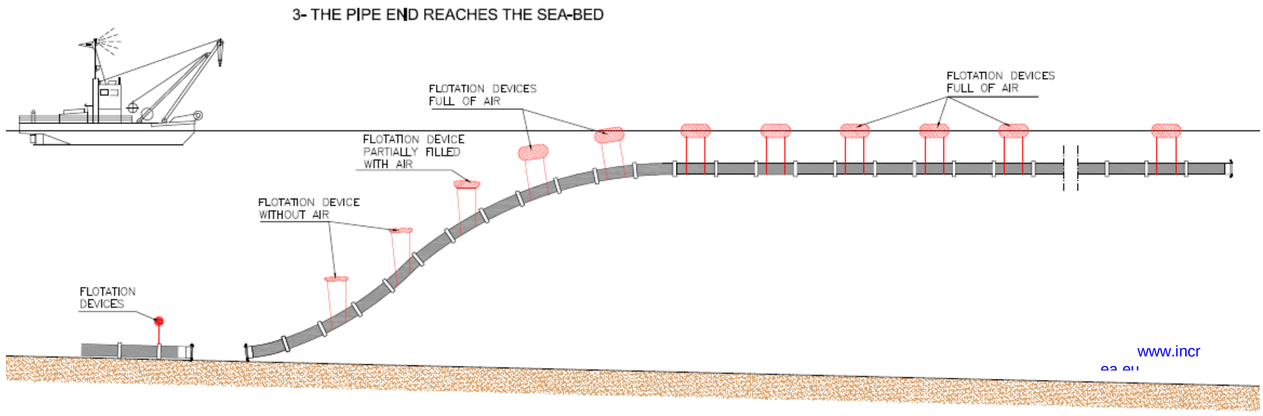

Figure 12: **Phase 3, The pipe end reaches the sea-bed**

Phase 4. – As the flotation devices continue to be flooded the classic “S” is generated (see in the following figure), and continues advancing until the complete sinking of the pipeline.

It is in this phase when the connection to the preceding pipeline should be carried out on the floor of the sea. Last works on the joint can be executed along the end of this phase and phases 5 and 6.

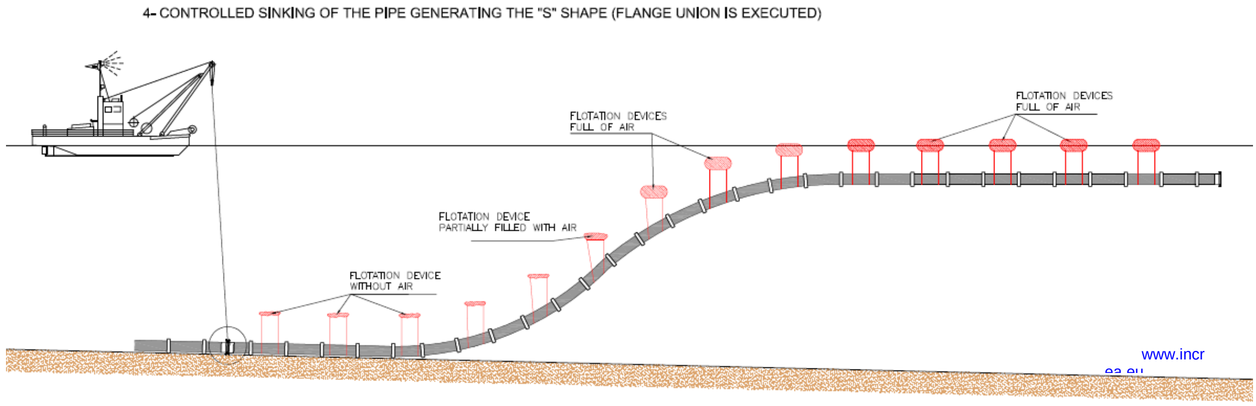

Figure 13: **Phase 4, Controlled sinking of the pipe generating the "S" shape (flange union is executed)**

Phase 5. – When there are enough flotation devices flooded, all of them leave the surface, and only the last few are left to flood, which still pull up the last part of the tube.

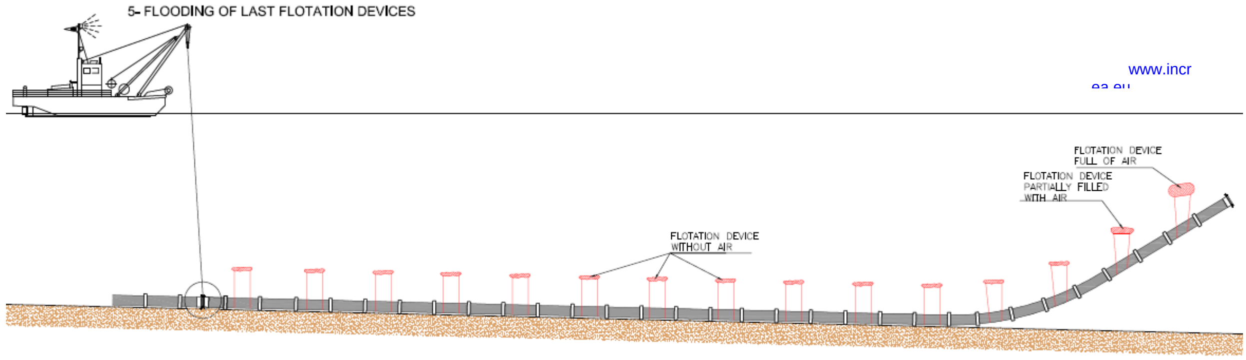

Figure 14: Phase 5, Flooding of the last flotation devices

Phase 6. – The pipeline lies on the bottom of the sea. Afterwards, all the flotation devices are untied and brought to the boat. The sinking of the pipeline is now completed.

CONCLUSIONS

PE pipes are the best choice for marine installations.

Basically, there are two types of production techniques: solid wall and helicoidally welded (structured pipes). When the flow rates through the pipes are high, the use of structured pipes can significantly optimise the design, given that the number of parallel lines can be reduced with greater diameters and; therefore, the total length of the pipe to be installed will be smaller. Lightening the pipe section with structured pipes means that a larger transversal stiffness can be obtained with less material, which means a significant reduction in costs.

Installation method should be carefully chosen and studied. If not, there is a risk to affect the structural integrity of the pipe.