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Inter-Island Freshwater Pipeline Installation Technology with TJ-19 Method

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Abstract The supply of fresh water for people who live on small islands but do not have a fresh water source is often a problem, especially regarding the selection of technology and raw water sources. So far, many people on the island who do not have a source of fresh water have to take water from a nearby island, or use rainwater during the rainy season. The use of technology that requires electrical energy and fuel will make the price of water expensive, so we need a fresh water supply technology that is easy to maintain and cheap in operational costs so that it can be done with local human resources and facilities. Pipe installation technology which is often used in gas and oil pipelines as well as electric cables requires special vessels which of course must be imported from other places, which will certainly have consequences for installation costs. If using this technology for installing fresh water pipes for domestic consumption purposes that are not business-oriented on a large scale, it is not suitable, so it is necessary to innovate so that pipe installation can be carried out at a lower cost which can also be installed by residents of the island, so that it will be easier for operation, maintenance and repair. The installation of an inter-island freshwater subsea pipeline using the TJ-19 method is very suitable because it does not require a special vessel and also does not require other sophisticated equipment, the installation can be carried out with a modified boat so that it can be used to install pipes more easily. The installation technique is to stretch the pipe in front of the boat for 100 m and at the end of the pipe, it is tied with a rope and given an anchor weight of 1,200 kg to maintain the coordinates of the pipe installation. Pipe installation is recommended when the maximum sea current speed is 0.8 m/s and the maximum wave height is 1 meter, so that the process of lowering the pipe can be carried out at the planned point.

Keywords Freshwater, Underwater, Inter-Island, Method, TJ-19

1. Introduction

Advances in science and technology have changed the pattern of human life in meeting their needs. One of them is the need for fresh water on small islands that do not have a fresh water source, which is carried out with various types of modern technology [1,2]. The provision of fresh water should be carried out using technology that is cheap and easy to operate and maintain, so that people are not burdened with high water prices. One of the technologies designed the supply of fresh water is a subsea pipeline by taking water from the nearest island and a gravity distribution system, so that there is no electricity cost in the distribution of fresh water [3,4]. Underwater pipe installation is generally carried out for oil, gas and electricity cables, while fresh water is rarely used [5-11].

This freshwater pipe installation technique also needs to innovate the installation method so that it can minimize construction costs [12]. The installation method must be carried out by taking into account the existing human resources and equipment in the area to be installed, so there is no need to bring in ships or special equipment, which of course will make construction costs expensive. In this design, pipeline installation techniques are studied that optimize local resources, both human resources and supporting facilities.

2. Installation Methods, Technical Aspects and Security of Pipe Position

2.1. Subsea Pipeline Installation Existing Method

There are four methods of installing underwater pipes that are often used, which are selected based on the conditions of the installation location, the four methods of the installation process are [13].

- Reel Lay method
- Towing method
- J – Lay method, and
- S – Layoi method

As for the underwater drinking water pipe, the TT method, can only be done at a maximum distance between islands of 1,600 m [12].

2.2. Technical Aspects of Subsea Pipeline

In the installation of subsea pipelines, water conditions must be considered, mainly ocean currents and waves.

(1) Effect of ocean current

During the pipeline installation process, ocean currents greatly affect the construction of the pipe which is perpendicular to the direction of the ocean current, so that the forces acting on the pipe are very large. The influence of ocean currents also occurs on ships, so it is necessary to calculate the exact anchor so that ships and pipes do not shift from the coordinates determined and work can be carried out at the maximum planned current speed. Figure 1 shows the force on the pipe caused by ocean currents.

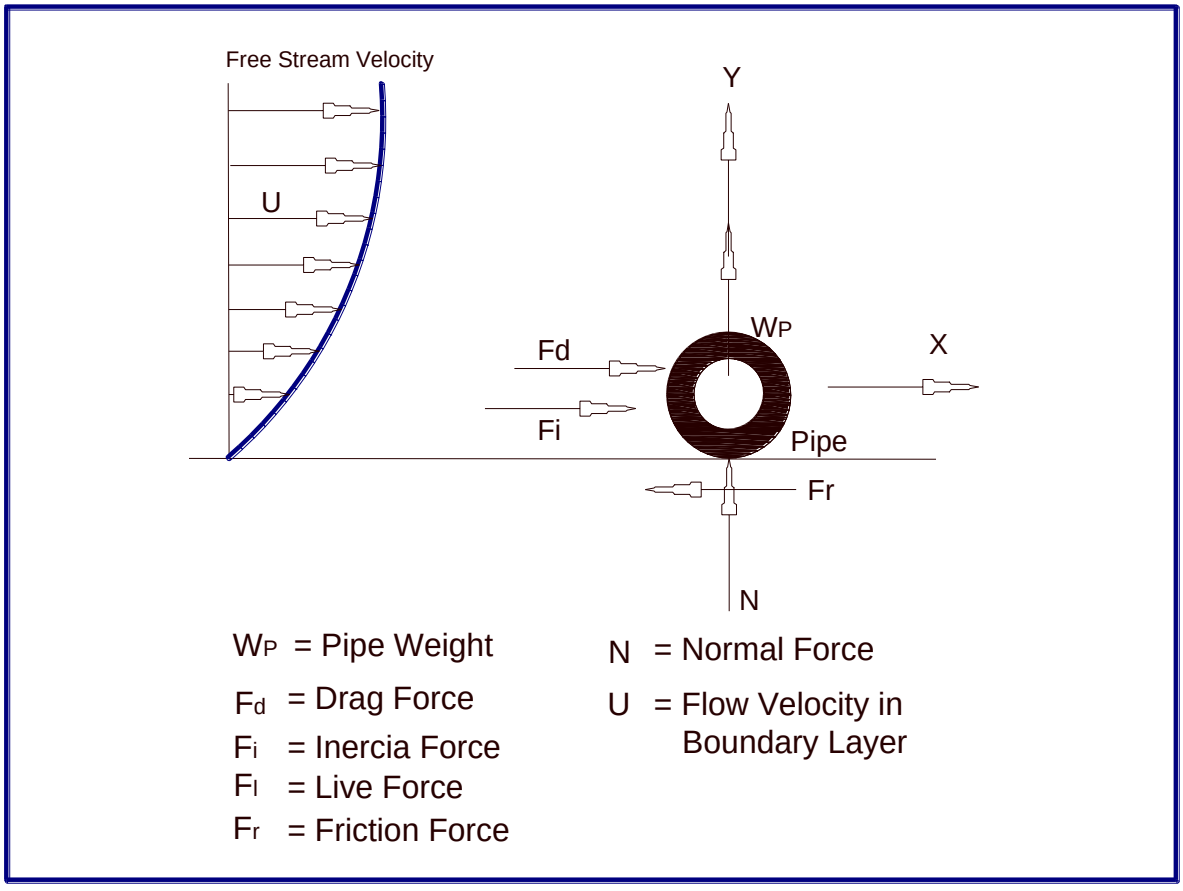

Figure 1. The forces on the pipe in water

(2) Effect of wave

The existing wave theory includes is Airy, Stokes, Gerstner, Knoidal and Mich. From a survey conducted in the Limbo strait, the wave characteristics tend to be in accordance with the Airy wave theory, one of which is a sinusoidal-shaped wave profile which is one of the characteristics of the Airy wave. [14-16]. The movement of the waves in the Limbo strait can be seen in Figure 2 which shows a sinusoidal wave. The process of installing submarine pipes using the TJ-19 method, which is carried out above sea level, is strongly influenced by wave conditions at the time of construction, so it must take into account the wave conditions so that the installation process can be carried out according to plan and does not endanger workers, equipment and pipes that have been and will be installed.

The effect of waves will be very large if the pipe construction is near the surface. The deeper the position of the pipe construction, the smaller the wave effect [17]. Figure 3 shows that the wave effect gets smaller at deeper positions and the wavelength bigger and deeper the effect is. Therefore, taking into account the existence of ocean currents and waves, the installation of drinking water pipes is carried out by laying on the seabed, so that the effects of waves, currents and deflections due to the weight of the pipe can be minimized. However, it is also necessary to pay attention to whether the pipe is on the seabed stability (seabed stability), as a result of the influence of pressure, the force acting on the pipe and the condition of the seabed, because if the position of the pipe on the seabed is unstable it will cause construction failure and the installation process cannot be continued. before any construction repairs are completed.

2.3. Pipe Position Security

The finishing work is carried out by diving to ensure the pipe and its ballast are in a safe location, not disturbed by corals or sea trenches which can cause local stress in the pipe which can cause failure [18]. The things that must be avoided are as shown in Figure 4, namely free spans, static stress and expansion control.

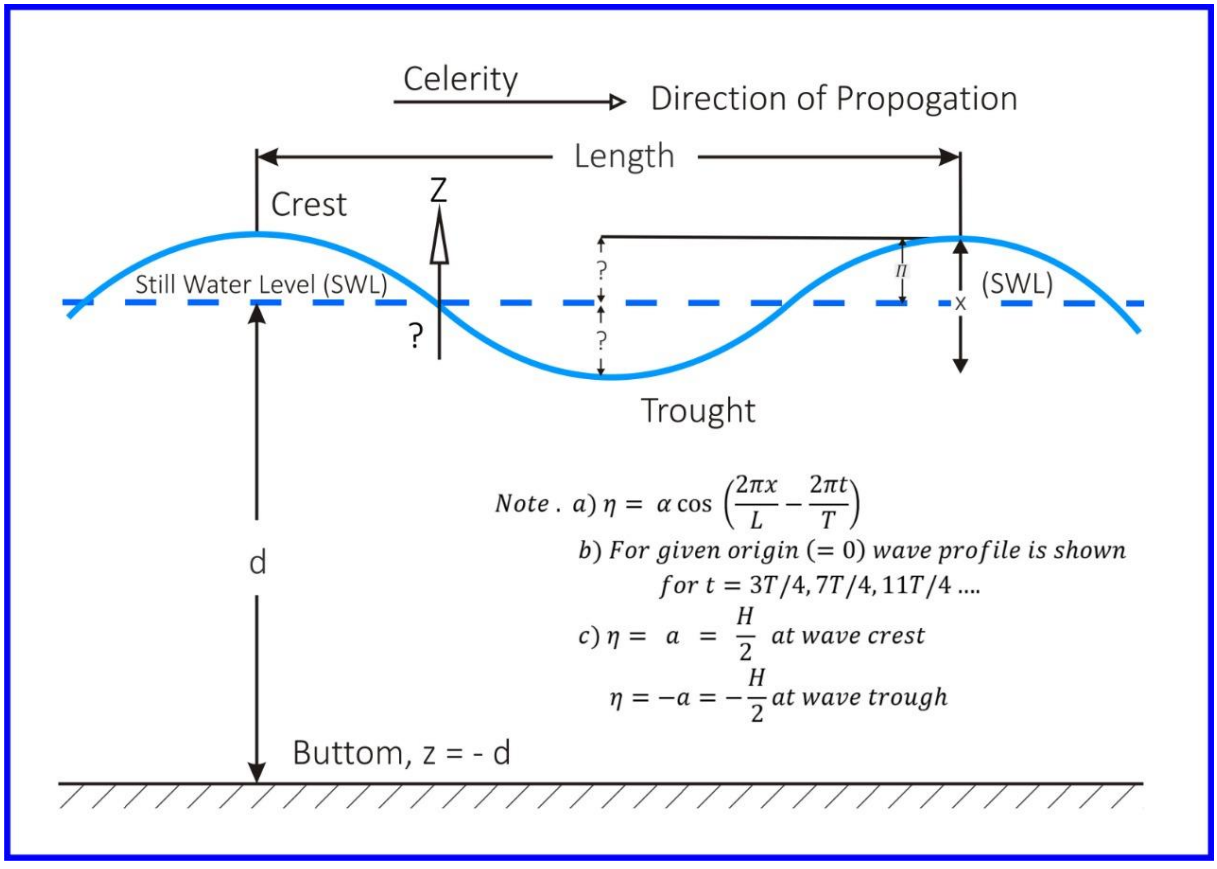

Figure 2. Wave movement

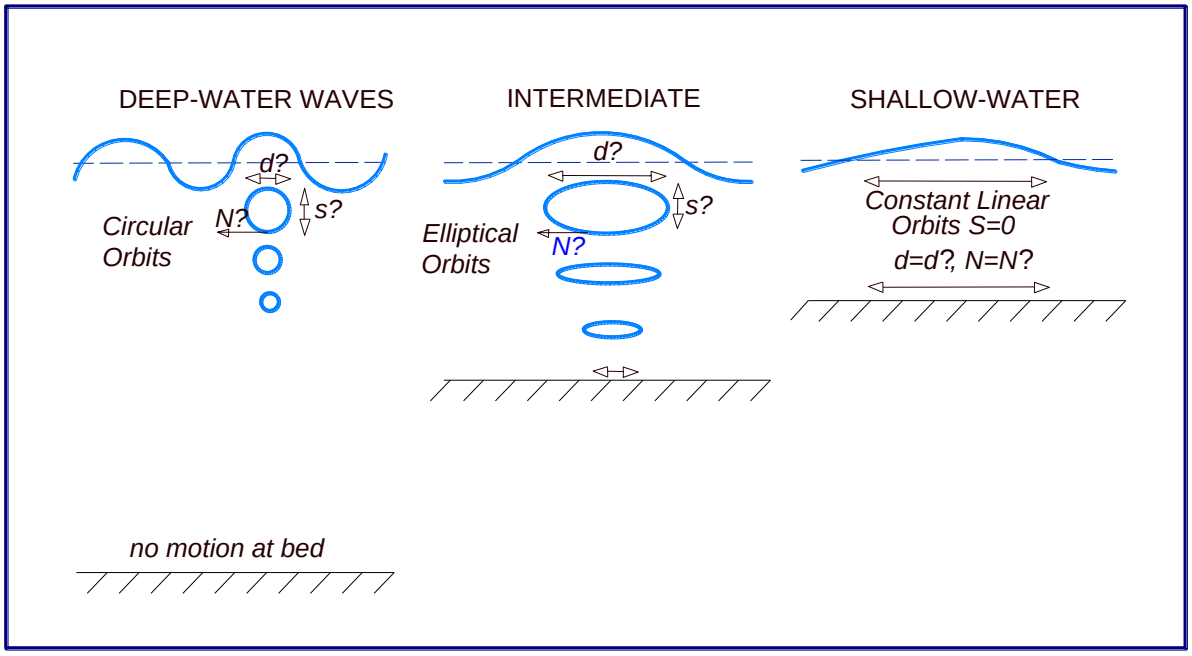

Figure 3. Wave effect on depth

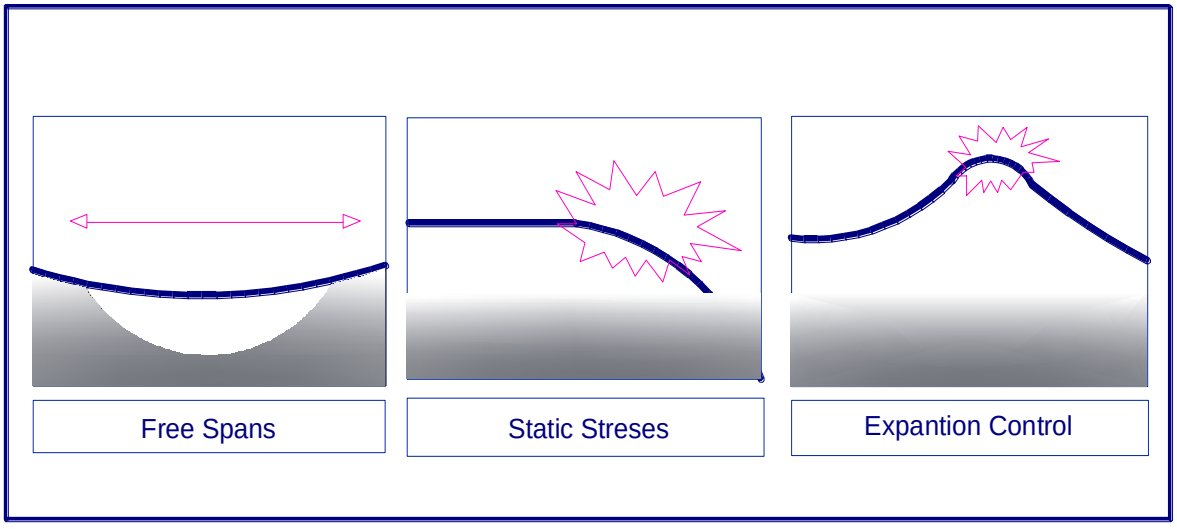

Figure 4. Things to avoid in subsea pipeline installation

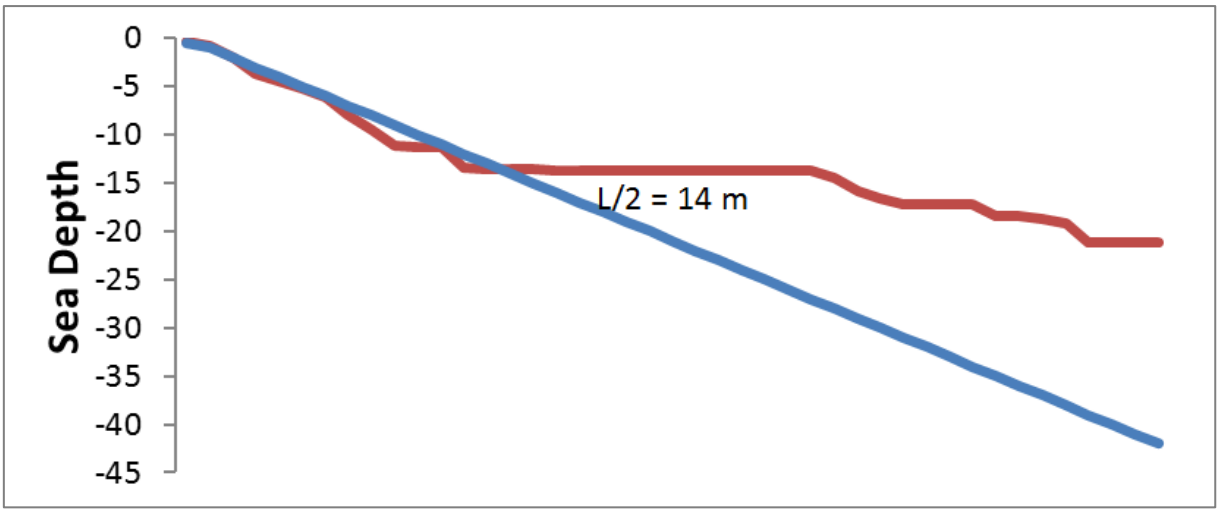

Figure 5. Boundary profile of wave influence on sea depth

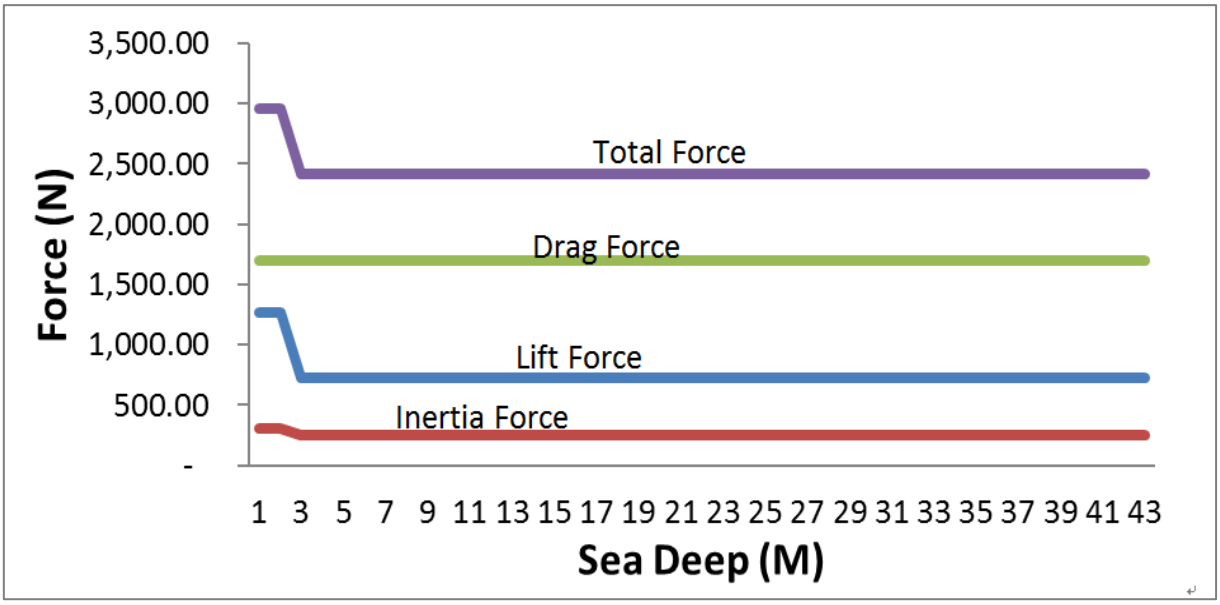

Figure 6. The forces acting on the pipe

3. Wave Effect on the Pipe

From the calculation results, it is known that the effect of waves on the structure of the underwater pipe is at a depth of 0-14 m, as shown in Figure 5 the profile of the influence of waves on the depth of the sea, The effect of waves on the underwater pipe structure is parallel to the position of the pipe, it is not like the direction of the current which is perpendicular to the installed pipe. So that in this calculation for sea depths above 14 m the effect of the waves is negligible or very small.

4. Force on the Pipe

Pipes on the sea surface are strongly influenced by ocean currents whose forces work perpendicular to the position of the pipe, as can be seen in Figure 6. Because the object that receives the force is a cylindrical pipe, the coefficient of resistance is $C_D = 0.47$.

5. Weight of Anchor

The process of installing subsea pipelines must maintain the coordinates towards the installation point, but because the installation direction is perpendicular to the ocean currents, an anchor is needed to maintain the position of the pipe [11]. In this method, the pipe to be installed is stretched per 100 m. From the calculation results, as can be seen in Figure 7, it is known that the pipe that floats on the surface experiences a drag force which if it is stretched longer it will receive a greater force from the movement of ocean currents. In this method, it is recommended to work

at a maximum sea current speed of 1 m/s, to maintain the safety factor of the pipe position and the safety of workers. To maintain the stability of the pipe above the water surface before being submerged, an anchor is needed per 100 m with an average weight of 577 kg. For anchor rope, it is recommended that it has specifications with a minimum breaking load of 600 kg. As a reference to see the weight and breaking load of the anchor rope in the installation of HDPE pipe with an outer diameter of 110 mm based on the speed of ocean currents, it can be seen in Figure 7.

6. Additional Mass

Additional mass is given to the pipe that is installed on the seabed so that the pipe is safe from various forces acting on the pipe, so that it does not shift from its laying position. For this reason, it is necessary to calculate the additional mass whose weight can overcome the various forces acting on the pipe.

Additional mass is given to overcome the various forces acting on the pipe on the seabed. In this calculation a safety value of 1.5 is given so that the additional mass can be calculated by the following equation:

$$_{ow} = F_{tot}$$

$$_{ow} = (\rho_c - \rho_{sw}) g . V_{wm}$$

So that the volume of concrete can be calculated by the following equation:

$$V_{wm} = \left(w_{ow}/(\rho_c - \rho_{sw})\right)/g$$

$$F_A = \rho_{sw} . V_{wm} . g$$

$$_{ow} = w_{oa} - F_A$$

$$_{oa} = w_{ow} + F_A$$

Where:

$$_{ow} = (\rho_c - \rho_{sw}) g . V_{wm}$$

Where:

F_{tot} : net force acting on the pipe (N)

ρ_{sw} : density of seawater (kg/m^3)

ρ_c : density of concrete (kg/m^3)

V_{wm} : volume of water displaced (m^3)

g: acceleration due to gravity (m/s^2)

$_{ow}$: weight of object in water (N)

$_{oa}$: weight of object in air (N)

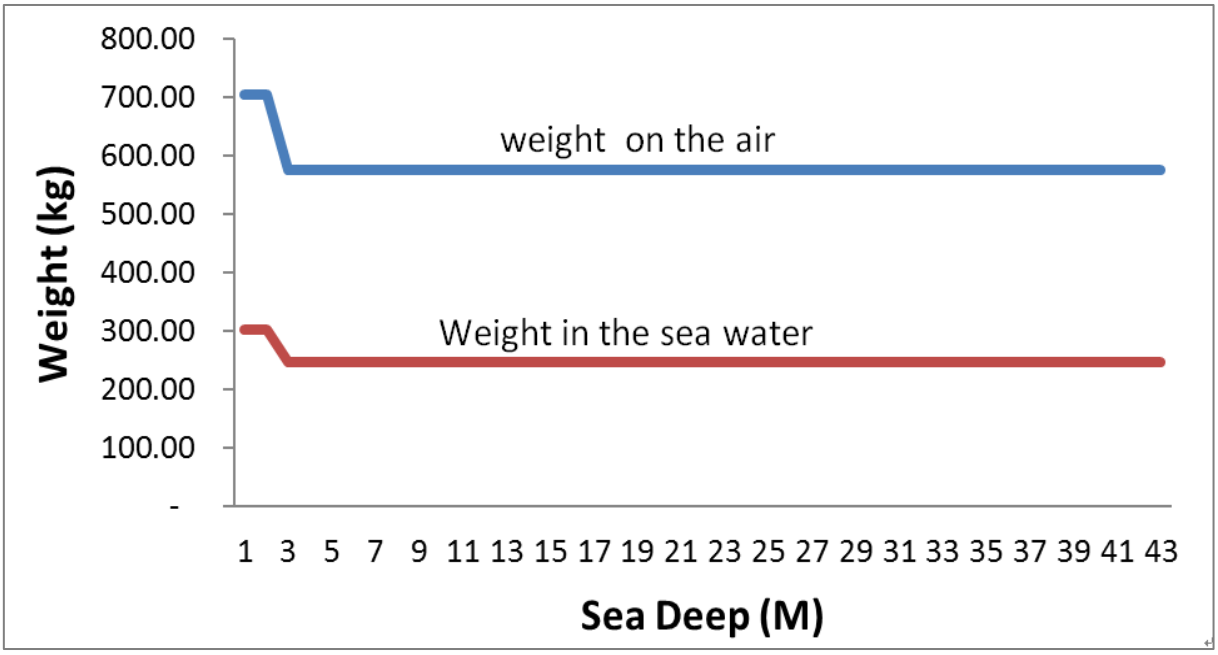

Figure 7. Additional anchor weights for pipelines extending at sea level

Figure 8. The Additional mass of pipe that has been installed on the seabed

Additional Mass calculations need to be carried out in the process of installing underwater pipes using the TJ-19 method, because it will greatly determine the type and size of the ship to be used, equipment and manpower. In this method, it must be ensured that the work can be carried out by workers with the help of simple equipment, so that this method can still be carried out with local labor and at a lower cost compared to the technique of using special vessels. Figure 8 shows a pipe that has been installed on the seabed with additional mass which is checked in position to ensure that the pipe is safe and does not suffer damage during the installation process with the additional mass that has been installed.

7. Pipe Connection

The connection of the pipe that will be stretched in front of the ship/boat is carried out in the same stages as connecting the HDPE pipe on land, but before connecting the pipe must be drained by draining fresh water from land, this is done to ensure that the pipe that has been installed is not blocked or damaged. After confirming the normal flow, the water flow is stopped for further pipe connection. The process of draining the pipes can be seen in Figure 9 and the connection of the pipes can be seen in Figure 10.

Figure 9. Drain pipe before connecting

Figure 10. The process of connecting pipes on ships/boats

8. Subsea Pipeline Installation with TJ-19 Method

Pipe laying with the TJ-19 method is carried out in several stages.

(1) The installation process is carried out starting from the coast of the island of origin to the island of destination, by extending the pipe that has been connected on land to the sea. The tip of the pipe at sea is tied with a coordinate anchor connected by a rope, so that the pipe installation direction is in accordance with the predetermined coordinates. The ship begins to install the pipe from the coast to the middle following the direction of the pipe.

(2) Installation The additional period is carried out on the ship's deck equipped with concrete binders and pipe clamps so that the concrete does not shift from the installation point on the pipe. The additional mass installation distance is adjusted to the results of the calculations that have been carried out at the planning stage. The weight of the concrete is cultivated to be able to be lifted by human power in order to facilitate the working process.

(3) The launch of the pipe to the seabed is carried out manually through a roller and to control the pipe so that it does not continue to enter the seabed before additional mass is installed, a rope and a control floater are provided. The floater installation also aims to reduce the load on the ship, especially the rear so that the ship does not sink.

(4) Laying the pipe on the seabed is done by releasing the floater that is close to the seabed, so that the pipe can be placed properly on the seabed. Floater removal is carried out by professional divers. The above method is carried out for pipe installation of a maximum of deep 50 meters, while for pipe installation with a depth of more than 50 meters,

the floater cutting is carried out at a depth of between 40-50 meters.

This process is carried out continuously until the pipe reaches the destination island.

Installation of additional mass concrete is carried out on ships/boats with a maximum recommended current speed of 0.8 m/s and a wave height of 1 m, and if the flow velocity exceeds 0.8 m/s and a wave height of 1 m, the pipe installation is at risk of moving away from the coordinates planned, construction failures as well safety of ships and workers. The schematic of the pipe installation technique using the TJ-19 method can be seen in Figure 11, which shows the position of the pipe being installed, and the installation of a floater so that the additional mass load does not burden the pipe before it is placed on the seabed. At the end of the pipe in front, an anchor is also installed as a guide for the pipe to match the predetermined coordinates.

The installation of additional mass and the pipe launching system can be seen in Figures 12 and 13. At this stage, the installation of additional mass is carried out according to the distance determined based on the calculation results. The installed auxiliary mass has a weight at sea level of 130 kg consisting of two parts connected by a 304 stainless steel bout.

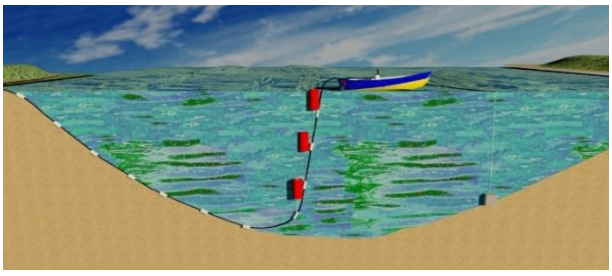

Figure 11. Schematic of laying subsea pipelines with the JT-19 method

Figure 12. Underwater pipe installation process with TJ-19 method

Figure 13. Pipe lowering process with TJ-19 method

9. Occupational Safety and Health

Installation of underwater drinking water pipes requires special attention, because the process is above sea level so it has many risks. In the work, the process must pay attention to the safety and security of all personnel involved in the work.

9.1. Work Safety

All workers must comply with standard operating procedures that are carefully determined, especially if this work is above the sea, the risk of accidents is very high both for workers and sea conditions. workers must be able to swim and must be provided with buoys, diving equipment and various equipment that supports work safety in the middle of the sea.

Workers must also be safe from electric currents from electric Welding machines of pipe and even wild animals in the sea, such as sharks and Stingray.

In addition, a personal accident with a high risk of accident is a ship accident and must be avoided early on. This ship accident has high potential because the position of the installation ship is always perpendicular to the direction of the ocean currents and in the direction of the waves, so that if the current speed is close to 0.8 m/s and the wave height is approaching 1 meter, the work must be stopped immediately while maintaining the position. the coordinates of the pipe that is installed by providing an anchor at the end of the pipe that is able to withstand various forces acting on the pipe so that the pipe is not shifted from the specified installation coordinate.

9.2. Occupational Health

Before starting work, all workers must be ensured that they are in good health. In addition, the work environment and equipment are also ensured to support the health of workers, whether it is a sanitation system, environmental hygiene, behavior, food, drinks including work equipment that will be used must not cause the risk of health problems including exhaust gas from engine ship.

10. Causes of Construction Failure

Pipe installations on the seabed especially those installed in straits have a high risk of construction failure, whether caused by sea conditions, the construction system or during the construction process. Pipe installation using the TJ-19 method is designed to minimize construction failures, which of course must be carried out in accordance with the correct stages and standard operating procedures. The form of construction failure is the occurrence of buckling in the pipe both during the installation process and caused by the influence of currents and waves after the pipe is installed. The condition that must be avoided in the installation process is that the position of the ship must not make the pipe angle less than 45^{o} from the end of the pipe on the seabed, this is where the weight and position of the coordinate anchor and floater are very important to be carefully considered so that the ship's position is not shifted backwards due to mass loads. addition. The next potential failure is the pipe breaking as a result of the inaccuracy of the connection process so that the pipe connection becomes defective. additional mass weight is also an important factor in causing failure of subsea pipeline construction, if the additional mass is not able to withstand the various forces acting on the pipe or vice versa, the pipe is not able to withstand the additional mass load that is too large, then the pipe will buckling and even break.

Some of the most important factors in this method are:

1. Anchor weight and rope specifications Anchor Coordinates
2. Additional Mass Weight of the pipe
3. The type of ship used, it is better if it is watertight
4. Buoyancy of pipe controlling floater
5. Supporting Vessels, namely concrete transport vessels and pipe connecting vessels.
6. Patrol vessels must ensure that there is no shipping activity sailing at the location of the pipeline installation.
7. A healthy and disciplined workforce with respect to the stages and standard operating procedures of the work.

11. Conclusion

Installation of underwater drinking water pipes between islands can be done using the TJ-19 method which is proven to be effective and does not require the support of special ships, special equipment or professionals with certain qualifications as workers, but can be done using 2 units of towed boats of each size is 5 GT each. This type of boat is easy to find in the islands, so it is easy to get one by renting or buying.

This method is also capable of installing pipes when the ocean currents move at a maximum speed of 0.8 m/s, making it possible to speed up the processing time, compared to the use of large ships that cannot be perpendicular to the current at rest. The length of the pipe to be submerged using the TJ-19 method is recommended to be 100 m, with the consideration that it does not require anchors whose weight is difficult to install manually. Due to the temporary nature of this anchor, it is better if the anchor is made of concrete so that it does not need to be lifted again, as well as being used as a pipe line marker. Installation of underwater drinking water pipes must pay attention to occupational safety and health issues that are in the process of being worked on, so that work accidents do not occur which can be fatal to the work and construction of pipes and ships used.

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