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TREND EDITORIAL

Trend of the environmental supervision on submarine pipeline installation

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Submarine pipelines are indispensable for marine oil and gas transportation and water supply to islands. They have been used to transport oil, gas, oil-gas mixture, or water (Qu et al. 2013). Construction method is very important for costly and time-consuming marine pipeline installation and should be selected after an overall consideration of technique, capital, and time (Wang et al. 2010). Moreover, the environmental impact and safety of construction, and its impact on the surrounding marine exploitation are also determinants. Besides common laybarge and tow methods (Sun 2012), subsea pipelines can also be installed by horizontal directional drilling (HDD), shield tunneling, and mine tunneling (Wei et al. 2012). During the pipeline installation of varying methods, both the environmental impact and key points of environmental supervision are different.

Outline of submarine pipeline construction methods

Laybarge

Laybarge method applies to the laying of long pipelines in the deeper seawater off the coast, being less susceptible to waves and enjoying a rapid construction speed (Wang et al. 2010). In terms of mileage, it is now the most common method of pipeline installation at home and abroad. According to the laying approach and the shape of pipelines in water, laybarge method can be further divided into three types: reeling, J-lay, and S-lay (Chen et al. 2013).

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The pipeline laying process is summarized as follows: pipes are firstly coated with cement onshore and then welded on a laybarge into a pipe string, which will be paid out to the seabed through the stinger at the proceeding laybarge's rear (Sun 2012).

Towing

Tow method applies to the installation of large-diameter, extra-heavy, bunched, or structurally complex pipelines, with no need of laybarge. The installation of such pipelines using the laybarge is slow and even unrealizable. Tow method is suitable for the following locations: the nearshore zones or shoals where the laybarge cannot be used for laying, or its mechanical operating is difficult or dangerous; the areas with severe sea or other environmental conditions where pipeline installation can only be carried out in a short period or intermittent seasons (Fang 1988).

Pipelines are welded onshore into a string and then towed along a slide into the water. Sometimes buoys will be deployed to lower the negative buoyancy of pipelines, so as to reduce the resistance against tugboats. Tow method has four types: surface towing, below-surface towing, on-bottom towing, and off-bottom towing (Zhao et al. 2008).

Horizontal directional drilling

Horizontal directional drilling applies to the routing area with severe sea conditions, where it is difficult to ditch for pipeline laying, and even if pipelines have been laid, they are vulnerable to seawater scouring, which is a hidden danger in the long run. The feasibility of this method depends on seabed conditions, drilling length, and pipeline diameter (Du 2007).

Multiple underground facilities (pipeline, cable, etc.) can be laid using the horizontal directional drill combined with a positioning and guiding system and a drilling and backreaming system, with the sea bottom kept intact. Track design,

drilling of pilot hole, reaming, and pipeline back-dragging are involved in this method (Liu et al. 2007).

Shield tunneling

Shield tunnel is driven under the seabed, which will not lead to seawater pollution. So shield tunneling is an environmentally friendly construction method. Featured by advanced skills and high degree of mechanization, shield tunneling applies to sand, soil and rock formations and can be adopted in any season. As a low-risk method, shield tunneling is generally used for excavating long tunnels.

Using a tunnel boring machine, the method can achieve one-step holing after continuous operations of tunneling, waste soil transfer, further tunneling, and lining assembly (Jia and Tang 2001).

Mine tunneling

Mine tunneling is to excavate a tunnel by drilling, charging powder, and blasting. In the tunneling process, concrete will be sprayed as an initial support. The method is often combined with shield tunneling method, wherein it is used to excavate a launching or receiving shaft for shield tunnel.

Environmental impact in the submarine pipeline construction

Of the construction methods above, laybarge and tow methods have a great impact on the marine environment as they involve seabed excavation, while the rest pose little threat to ocean.

Environmental impact of seabed excavation approaches

The pipeline installation based on the laybarge method will inevitably produce waste gas, noise, and solid waste. Besides, it will carry sediments to the water when laying pipelines at the seabed and excavating the shoal at the landing terminal (Zhang 2003). The sediments formed in pipeline laying are mainly attributed to the submarine disturbance from high-pressure water, plows, and ditchers which are used for groove excavation. The yield of suspended sediments is calculated according to laying speed, embedment length, sediment density, and sand-raising rate. At the landing terminal, some sediments will also be formed in the operation of amphibious excavator and hydraulic laying machine. Furthermore, the improper disposal of the water for pipeline pressure testing after pipeline installation will also pose a threat to the marine environment. The environmentally unsound processes of the laybarge method are illustrated in Fig. 1.

Like the laybarge method, the tow method may have an adverse influence on ocean environment when laying pipelines at the seabed and excavating the shoal at the landing terminal.

Environmental impact of other construction approaches

Taking shield tunneling method as an example, the environmental impact of other construction approaches is introduced below. Shield tunneling is generally combined with mine tunneling, wherein the former is used for driving under the

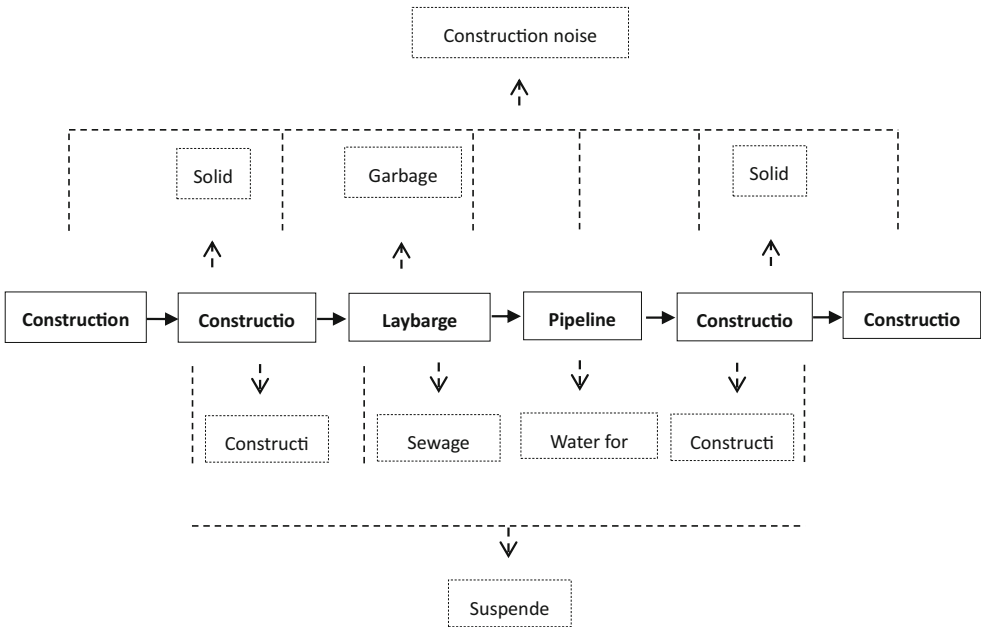

Fig. 1 Environmentally unsound processes in the laybarge-based pipeline laying

seafloor and the later for digging a launching or receiving shaft for the shield tunnel.

Launching and receiving shafts are the main sources of pollution during the construction. Besides, waste water, blasting dust, and solid waste may be produced in the driving of a shield tunnel, and noise and exhaust by machines. The outputs of domestic wastewater and garbage can be estimated by the number of constructors. The slime water produced in shield tunneling can be quantified according to the processing amount, operating time, and slurry separation rate of the slurry separation plant. The environmentally unsound processes of the shield tunneling method are illustrated in Fig. 2.

The main pollution in horizontal directional drilling includes the wastewater and solid waste in the construction process, as well as the noise and tail gas of machines, which is similar to shield tunneling. Both methods have a small impact on the marine environment.

Key points of environmental supervision on submarine pipeline installation

Seabed excavation approaches

1. Limiting the boundary of construction area. The boundary of construction area should be strictly controlled, to reduce the impact on ecological environment as much as possible.
2. Strict supervision on construction technologies and machinery. Construction technologies and the type and number of construction vessels must be consistent with those in design and environmental impact assessment. Otherwise, the suspended sediments produced in construction probably have a wider impact than the expectation by environmental impact report. The actual scope of the influence of suspended sediments should be compared with the predicted scope through the field monitoring in construction period. If the difference is great, sensitive areas should be identified again.
3. Environmental supervision on construction vessels. ① The oil pollution from construction vessels should be checked to prevent massive oil leak. The washing of fuel tanks and pollutant containers is impermissible within the marine construction area. Only after the approval by port supervision department can the residual oil of fuel tank and engine room be cleared for vessel maintenance, and the drawn residual oil must be taken back and disposed by qualified institutions. ② Another supervision item for construction vessels is the reserve of chemical oil dispersants and absorbents. The storage of these chemicals should agree with the requirement of environmental impact assessment, and a contingency plan should have been prepared.
4. Seawater quality and marine ecological environment are the emphases of environmental monitoring in construction period and should be monitored by qualified institutions. ① To check the seawater quality, suspended particulate matter (SPM), chemical oxygen demand (COD), and petroleum at 100 m, 500 m, and 1000 m away from both sides of the pipeline crossing zone should be tested. The number of testing stations should be determined by the pipeline length. One monitoring should be conducted

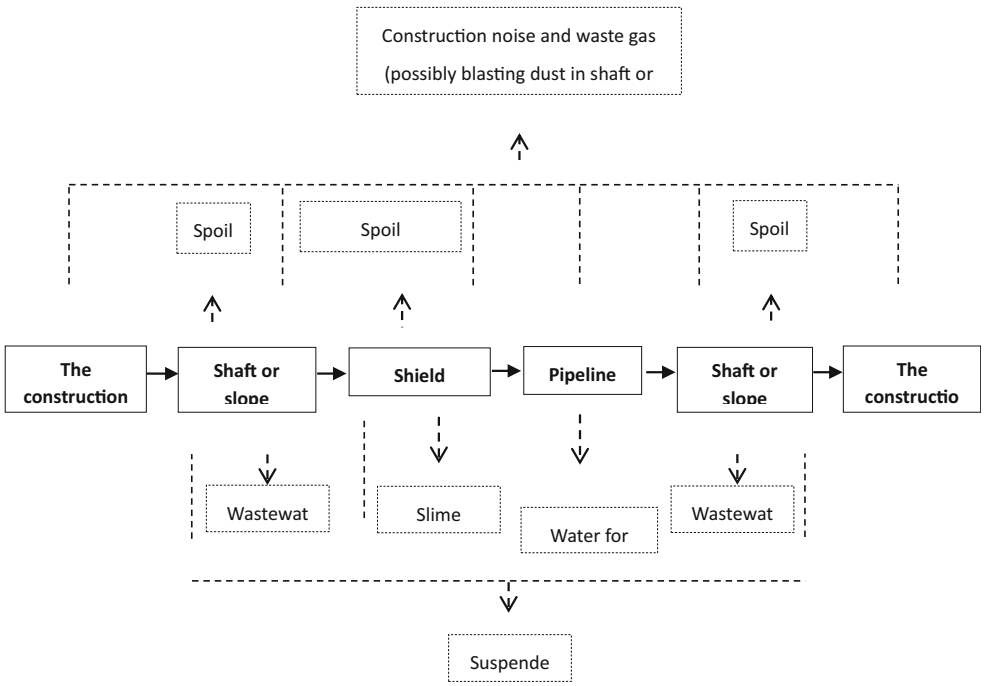

Fig. 2 Environmentally unsound processes in shield tunneling

separately in spring tide and neap tide. ② Chlorophyll a, fish eggs and larvae, phytoplankton, zooplankton, and benthos should be monitored as indicators of marine ecological environment. The monitoring sites are 500 m and 1000 m away from both sides of the pipeline crossing zone, and their number is determined by the pipeline length. The monitoring frequency is once each year.

Other construction approaches

1. Supervision on ecological protection measures. ① Strict supervision should be adopted to ensure that the construction party will abide by construction plan and design, protect and reasonably utilize land resources, and work in appropriate range and way. Besides, the construction party should adopt active measures to prevent and control the water and soil erosion and environmental pollution caused by their construction or other activities. ② Whether the measures for natural ecological protection and rehabilitation, soil and water conservation, and protection of environmentally sensitive regions (natural reserve, scenic spot, water conservation area, etc.) are put into practice in the construction process should be supervised. The specific measures needed to be supervised are as follows: engineering measures for soil and water conservation; migration, protective isolation, animal corridor construction, habitat environmental improvement and artificial propagation for wildlife protection; other ecological protection and recovery measures in or after the construction, such as restoring farmlands and grassland or forest.
2. Supervision on pollution level. ① Sewage discharge: The slime water, pressure testing water, and domestic water produced in the construction process cannot be discharged before reaching relevant standards through purification. The source, type, concentration and volume of different wastewater, and their discharge location and type should be investigated. Besides, whether the wastewater of varying types produced in the construction period is disposed properly should be checked. In shield tunneling, the disposal approach, disposal location, and transport way of the slime water need special attention. ② Air pollution: Whether the construction party adopts proper protective measures (watering, drilling and blasting, etc.) in temporary dust producing areas should be checked. The atmospheric environment quality of the construction area should be monitored. In addition, the reasonability and feasibility of dust prevention measures should be assessed. ③ Noise pollution: Whether vibration damping and noise attenuating measures are adopted in drilling and blasting should be supervised. The layout, operating time and movement route of main noise-producing equipments should be monitored and controlled to reduce the impact on surrounding residents and wildlife. ④ Solid waste production: Solid wastes from the construction should be timely transferred to the dumping site which has been selected in water conservation scheme. In rainy season, effective disposal and sheltering measures should be adopted for the slime water to be transferred.
3. Supervision on environmental protection facilities Supervision and inspection should be implemented to determine whether the facilities for pollution treatment and environmental risk precaution are built according to the requirements of environmental impact assessment and its approval document. The scale, quality, and construction progress of the facilities treating sewage, waste gas, noise, or solid waste also need to be inspected.
4. Construction noise and dust are the emphases of environmental monitoring in construction period and should be monitored by qualified institutions. ① The noise at the boundary of industrial enterprises, L_{Aeq}, is taken as the noise index at construction site. As the name implies, the monitoring sites are set at the boundary of the project area. Daytime and night noise will be tested once each season. ② To depict the status of the construction-induced dust, total suspended particulate (TSP) is monitored at the villages which construction vehicles pass by, construction sites, and both sides of the roads taken by the construction vehicles. The number of monitoring sites depends on the construction route. The monitoring frequency is once each season.

Discussion

1. The environmental supervision on submarine pipeline engineering is greatly influenced by construction method, due to the special construction environment, vessels, and machinery. The range and pattern of the environmental impact will vary with construction method (Yu et al. 2015). Among the five construction methods above, those involving seabed excavation have a great impact on construction waters, while the rest only need the environmental supervision similar to that for onshore pipeline engineering. Hence, the priority of the environmental supervision on a submarine pipeline engineering is to understand its construction technologies and possible environmental impact.
2. High demand on supervision level. Submarine pipeline engineering has higher demands on environmental monitoring equipments and personnel than the onshore one. Strict demand on scientific and technical specifications and monitoring (Niu and Jin 2009). In submarine pipeline construction, monitoring instruments should conform to the requirements of marine engineering supervision. In

the meantime, monitoring personnel should have an educational background related to marine monitoring. They should be clear about what, how, and where to monitor. At present, there are few qualified institutions engaged in ocean environmental monitoring. That is why the current environmental monitoring in submarine pipeline construction has not been satisfactory yet.

3. Vigorous ocean exploitation energizes the development of subsea pipeline engineering. As the construction method changes, the environmental impact and key points of environmental supervision will be different. In practice, an intensive analysis should be performed by combining with specific construction scheme, so as to improve the environmental supervision on subsea pipeline installation. Thus, the impact on ocean environment can be reduced as much as possible. High expertise demand Environmental supervisors should have basic knowledge of oceanography, be familiar with marine engineering characteristics, and know the similarities and differences between the environmental impacts of offshore and onshore pipeline installation.

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