곡선 구간의 복합 해저관로 적용 사례

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Application of dual offshore pipelines in curved route

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KEY WORDS : bundle pipeline 번들 관로, curved route 곡선 구간, bottom pulling 해저풀링, subsea guide pile 해저 가이드 파일

ABSTRACT : 곡선 구간에 복합 해저관로를 설치하기 위해서는 한 개의 관로를 설치하는데 필요한 설계 및 장치보다 더 많은 사항들을 고려해야 한다. 본 논문은 두 개의 복합 해저관로를 설치하는데 필요한 각종 설치 설계 및 장치 설계를 비롯하여 개발된 특수 장치들을 소개한다. 두 개의 해저관로의 외경은 30 inch, 두께는 17.5 mm, 콘크리트 코팅은 70mm이고 3.007km의 노선 중 약 1km가 곡선 구간이다. 최대 수심은 34m이고 약 7.5m의 조수간만의 차를 갖고 있는 지역이다. 해저 곡선구간에는 18개의 해저 가이드 파일을 설치하여 곡선부에서 요구되는 반경을 확보하였다.

INTRODUCTION

After the first bundled pipeline installation by bottom pull in Singapore in 1981, there have been a number of single and bundled pipelines installed by bottom pull technique in Asian region. (Ngiam and etc. 1998) As the oil and gas import and oil products expert increase there are number of pipelines are constructed recently in the region. In 1998 there was a challenging project of three bundled pipelines connecting Inchon to Yong Jong new airport. That was the bundled pipeline of three non-symmetric meaning that each pipe had different specification with various outer diameters, wall thickness and coating. This project has been completed successfully in Oct. 1998. (Jo, 1999)

In this paper, the bundle pipeline with 1.0 km curved section in 3,007 m entire route is introduced. Since the pipeline was to be bundled, various devices and engineering were investigated to pass this curved region. The bundled pipeline consists of two 30" gas lines with 17.5 mm wall thickness and 70 mm weight coating. The maximum water depth reaches up to 34 meter from mean sea water level. The construction area is characterized with the maximum of 7.5 meter tidal range with more than 4 knots current. To install the pipeline, a bottom pull method was adopted considering the available space of onshore string fabrication yard, marine traffic and strong current in the region. To apply this method, individual pipe joints are aligned and welded into continuous pipe strings of 96 meter long and bundled with other pipe strings. For the curved region, 18 subsea guide rollers were designed and installed at various spaces being satisfied the allowable stress of pipeline. The subsea piles were designed as per the roller reaction force from the analysis. Several devices and equipment were invented and designed for the project. An onshore turning sheave was designed for continue pulling with the crane barge without any onshore equipment assisted or mobilized. The running hold back and standing hold back systems were used to help welding and launching operation of pipeline strings.

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PIPELINE DESIGN

The pipeline route is to be selected carefully considering several factors including local marine traffic condition, environmental and operational requirements and government statutory requirements. (API, 1992 and DnV, 2000)) For the subject pipeline, since there were mooring dolphins existed along the strait pipeline route, it was to avoid the existing facilities as shown in Fig. 1. Since the pipeline route crosses the ship channel, the protection again the anchor drop was required. It was confirmed that along the route, there was no pipeline or cable existing. The pipeline was laid in pre-trench being protected from anchoring. The trench depth was determined considering the average anchor size of the maximum deadweight of vessel sailing over the pipeline route.

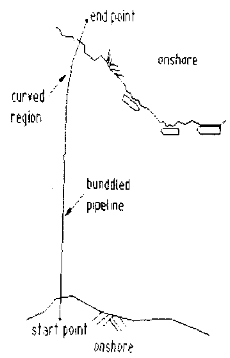

Fig. 1 Pipeline route

The design environmental data of the region is as shown in Table 1.

Table 1 Environmental data

DESCRIPTION	VALUE	REMARKS
Wave length (m)	19.0	
Wave height (m)	1.7	
Wave period (sec)	5.0	
Current velocity (m/s)	2.0	4 knots

Other environmental data, such as wind, temperature, storm etc. are not presented in the paper. The tidal range of 7.5 meter is applied in the design considering the installation period.

The pipeline specification is summarized in Table 2.

Table 2 Pipeline specification

DESCRIPTION	VALUE	REMARKS
Pipe O.D. (mm)	762	
Wall thickness (mm)	17.5	
Concrete coating (mm)	70	
Ext. corrosion coating (mm)	3.5	
Density of ext. corrosion	940	
Density of concrete (kg/m3)	2300	
Density of seawater (kg/m3)	1025	
Density of steel (kg/m3)	7850	
Steel dry weight (kg/m)	321.3	
Total dry weight (kg/m)	753.6	
Buoyancy (kg/m)	665.2	
Sub. weight (kg/m)	-88.4	
Water absorption (kg/m)	9.46	
Total sub. weight (kg/m)	-97.9	

The negative sign in the table stands for sinkage.

INSTALLATION ENGINEERING

The selection of pipeline installation method is very important since it closely relates to the determination of equipment type, personnel, construction schedule and cost of project. Depending on pipe specification, environment, site condition and available equipment, an appropriate method is to be decided. Having considered several factors such as marine traffic, strong current, string fabrication yard and so on, the bottom pull method was determined in the project execution.

Pulling Method

Since there is a tide with over 7 meter difference, the pulling force during high and low tides varies. The pulling force was estimated with four contact conditions, 1). dry on roller, 2) 50% dry on roller, 3) 100% submerged on roller and 4) 100% submerged on seabed. Without buoyancy devices, the maximum pulling force for high and low tides were calculated as 637 tons and 654 tons respectively. However, since the generally available winch capacity was around less than 250 tons, a crane barge with 1000 tone lifting capacity was mobilized. A turning sheave was designed and installed on the bow of the barge to convert the vertical pulling force to horizontal force. With steel buoy tanks attached to the bundled pipeline, around 350 pulling force was achieved. Since the back-filling would increase the pulling force, around 10% of load increase was taken into account in the installation engineering.

A 1000 ton crane barge was used to pull the pipeline. For a continuous pulling up to the reaching point on the other shore, a turning sheave was designed as shown in Fig. 2. The turning sheave acted as a turn table where the wire went around it so that the pulling operation could continue with the barge positioned offshore area where the water depth was deep enough for the barge.

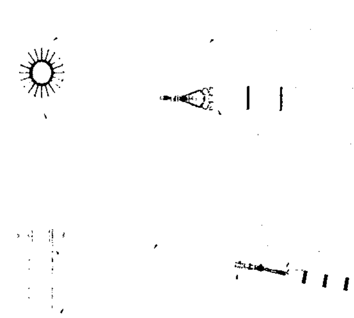

Fig.2 Turning sheave arrangement

Buoyancy Device

Buoyancy devices were attached to bundled beams to reduce the pulling load. The quantity of device was decided to achieve the maximum pulling force of around 350 tons. The thickness and side plate of buoyance were calculated considering the external pressure. The buoyance device was also designed to covert as the additional weight in case of unexpected storm condition by filling the tank with water. There were also two ball valves attached for safe water filling and air injection. These valves were also useful when divers remove them safely under control avoiding possible pop-up situation.

Launchway

The launchway configuration is very critical in bottom pull method. There are several factors to be considered to plan the launchway and string fabrication yard. The dimension of string fabrication yard is mainly dependent on the available site space. If the string can be made long, it significantly reduces the pulling time by minimizing welding process, NDT and coating. For the launchway, several factors are to be considered to determine the profile:

- pipeline stress
- allowable bending radius
- roller space and reaction force
- separation between pipeline and rollers
- allowable pipeline span
- deflection at welding station
- alignment of strings for welding
- interference with roller guide and sheet pile structure if there is any.

It is desirable to have a short touchdown length in order to achieve the better stability of the pipeline being on contact with seabed (Jo, 1998). In the design, pipeline stress, roller reaction, separation, etc. can be estimated. Another important aspect in the analysis is to investigate the deflection and alignment at welding station. This can be estimated by continuous beam theory by adjusting the roller height and space. For bundled pipelines, the stiffness being bundled influences on the deflection of pipeline. The bundle beam type and space should be considered in the analysis (Yong, 1998).

Pulling Head Arrangement

Pulling head was specially designed for the bundled pipeline with many functions; pulling itself, buoy, and skidding as shown in Fig. 3. Considering possible increase of pulling force due to lateral current, back-filling, up-slope, etc. the pulling head components should be designed to cope with the possible increased force. The pulling head arrangement consists of pulling head, swivel and shackles. In the pulling head there were two pigs for contingency plan and for cleaning afterward. The size of trench section was determined considering the width of pulling head arrangement.

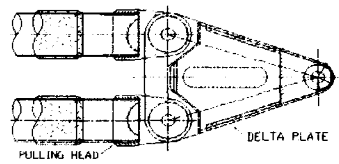

Fig. 3 Pulling head and delta plate

Subsea Guide Roller

The most critical device was the subsea rollers to guide bundled pipeline along the curved region. The pipeline stress and support reaction are dependent on pipeline specification, applied tension, number of piles, space and curved radius. In this study, the pipeline data was given and the maximum pulling force was obtained with applied buoys. Various curve radiuses were investigated. Five radiuses with 18 pile supports at even space; 580m, 786m, 990m, 1195m and 1400m, were applied considering the available site conditions. As shown in Fig. 4, as the radius increases the stress on the pipeline reduces. Figs. 5 and 6 show the pipeline stress and support reaction force versus number piles. Fig. 7 shows the support reaction versus distance from the start point. As indicated in the figures, the even space cause un-even stress and reaction distribution. By adjusting the pile space, the stress level and reaction force can be improved.

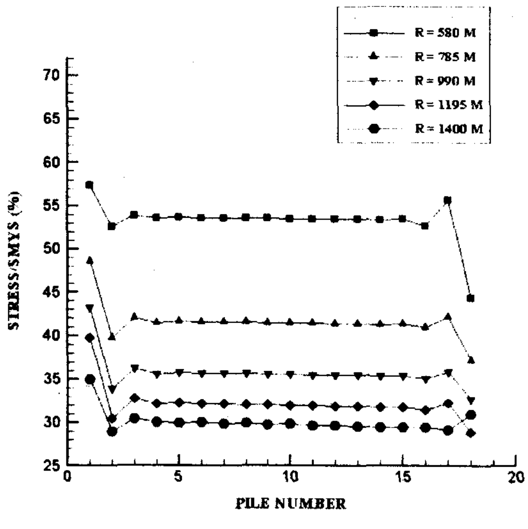

Fig. 4 Pile number vs. stress

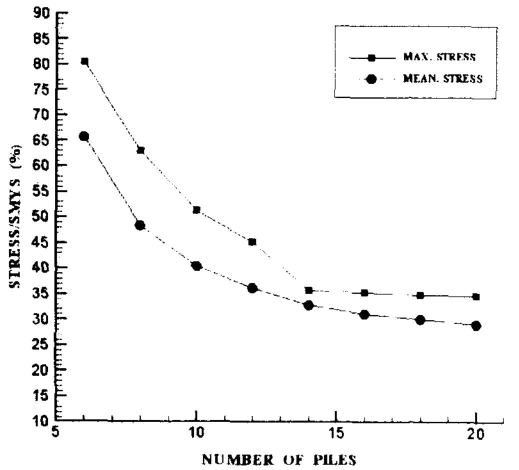

Fig. 5 Number of piles vs. stress

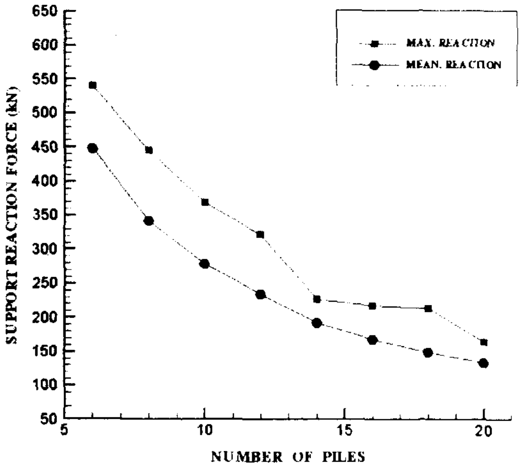

Fig. 6 Number of piles vs. support reaction

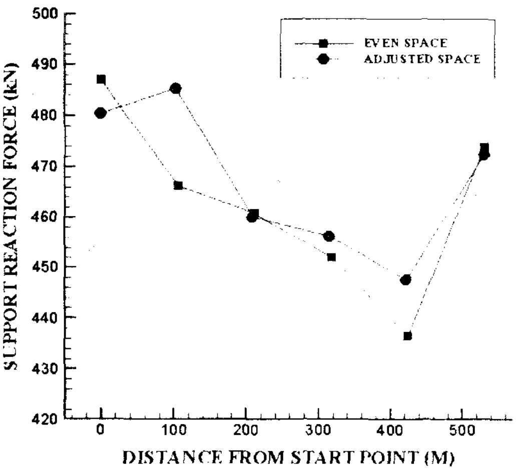

Fig. 7 Distance vs. support reaction

Fig. 8 shows the launchway configuration. To control the pulling process, the running hold back winch and rigging system are placed at the end of launchway. Also the standing hold back system is shown in the same figure. Fig. 9 shows the subsea guide rollers. The rollers were specially designed as per the estimated support reaction forces. Fig. 10 shows the pulling head arrangement consisting of delta plate for bundled pipe pulling and pulling head with skid and buoy attached. In front of delta plate, there is a swivel tied to prevent twisting or torsion which might occur during the pulling operation. Fig. 11 shows the bundled pipelines on launchway.

CONCLUSION

Even it is possible to install a bundle pipeline in a curved route, various engineering and equipment are critically required. The precise design and estimation of each component are to be carried out to avoid any failure during operation. Construction period and cost can be significantly saved by installing two lines at the same time. However, the operation requires very close coordination among all the involving parties; crane barge, turning sheave engineer, launchway operator, marine traffic controller, divers, etc.

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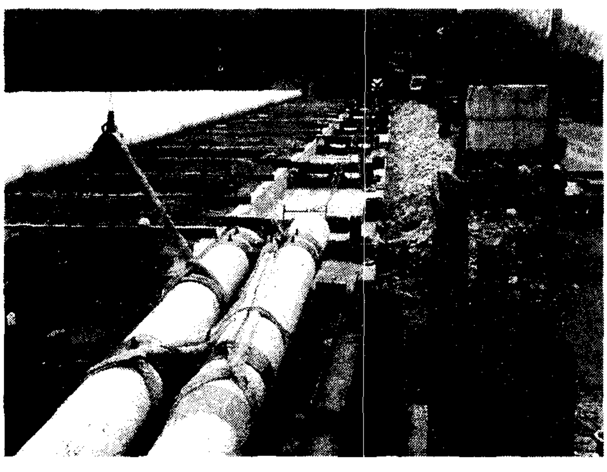

Fig. 8 Launchway configuration

Fig. 9 Subsea guide rollers

Fig. 10 Pulling head arrangement

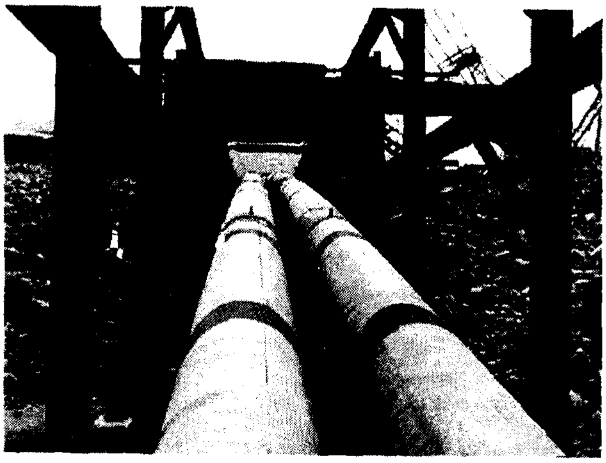

Fig. 11 Bundled pipelines