The Design and Construction of Ocean Outfall Diffuser for Samut Prakarn Wastewater Management

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Summary

The Ocean Outfall Diffuser system is a mechanism for transmitting and dispersing of treated wastewater from the shore to the ocean through a submarine pipeline. The original concept envisaged a gravity flow pipeline to be installed below the seabed. Among several construction alternatives proposed, the inverted tunnel siphon constructed by a tunnelling technique is preferred. The inverted tunnel diffuser system comprises (1) an onshore shaft and an offshore shaft, located 2,620 m apart; (2) a segmental tunnel with an inside diameter of 2.6 m, connecting the two shafts at the elevations of -26.0 and -23.0 m MSL, respectively; (3) a submarine pipeline (diffuser header); and (4) 100 risers spaced equally on top of the diffuser header, extending 0.7 m above the seabed for dispersing the treated wastewater to the ocean. The design, analysis and the construction procedures of the onshore and offshore shafts, submarine pipeline, and temporary structures for launching the onshore and offshore shafts are presented in this paper.

Keywords: Outfall-Diffuser, Onshore Shaft, Offshore Shaft, Inverted-Tunnel, Riser

1. Onshore Shaft

The Onshore shaft is designed as a caisson with the inside diameter of 9.00 m and thickness of 1.00 m. The top and bottom elevations of the shaft are +4.0 m and -30.0 m from mean sea level (MSL) respectively. Groundwater level is –10.0 m MSL. The loadings taking into account are earth pressure, groundwater pressure, effluent pressure and thrust force induced by the tunnel boring machine (TBM).

During construction, groundwater combining with earth pressure will induce compression in the shaft’s wall. However, the treated effluent with hydraulic head of +11.0 m MSL in service condition will induce the tension in the wall of the shaft.

Three construction alternatives for installation of the onshore shaft were explored: Diaphragm-Wall, Secant Piling, and Cast-In-Situ Shaft with Hydraulic-Jack Controlled Sinking System. Taking into account of construction cost, contractor’s capability and resource, Alternative 3 is employed.

The system comprises the construction of cast-in-situ reinforced concrete shaft, soft eyes and end plug. Hydraulic jacks and screw jacks are monitored and adjusted to ensure that the sinking shaft is plumb at all time. Bentonite slurry is employed to reduce the skin friction. Ring beam for supporting eight sets of hydraulic jacks and screw jacks was constructed on pile foundation.

Reactions at all eight supporting hydraulic jacks have to be kept below 1,960 kN during sinking. Water and soil quantity inside the shaft has to be calculated to prevent base heave. Buoyancy is calculated based on the specific gravity of both salt water and 1,400 kg/m^3 mud. The onshore shaft is a cast-in-situ reinforced concrete structure.

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The shaft was cast incrementally with an increment of 3.0 to 3.5 m in height. Concrete casting and shaft sinking were carried out alternately. The shaft was equipped with steel cutting shoe, piping for bentonite injection and cement grouting, and eight steel brackets to transfer the weight to the jacks.

The sinking was proceeded by stroking down the screw jacks and hydraulic jacks, respectively. When the top of the cast segment reached the elevation of 1.0 to 1.5 m above the ring beam, a new segment was cast on the top of the previous one.

During the sinking of the shaft, excavation was carried out methodically to avoid bottom soil heaving. Once the tip of the shaft reached the elevation of –30 m MSL and the excavation completed, cement grout is injected to replace the bentonite and act as rust protection of the rebars. The reinforced concrete plug with thickness of 3.0 m was installed at the bottom of the shaft.

2. Offshore Shaft

Offshore shaft is designed as a caisson as the onshore shaft but with precast segments. The bottom and top elevations of the shaft are –27.0 and +4.0 m MSL respectively.

Vertical and lateral loads acting on the offshore shaft are similar to those of the onshore shaft except for buoyancy, which is calculated from sea level instead of groundwater level

Since the offshore shaft consists of precast segments, structural analysis has to be performed on segmental structure to closely simulate the actual condition as much as possible. Each segment connects to one another by tension links

Two alternatives were explored for launching the offshore shaft: Sand Island with Temporary Platform, and Polygonal Platform with Sheet Pile Cofferdam. Since the seabed is very soft clay down to about 15 m deep, Alternative 2 is more economical.

The system comprises the construction of polygonal steel ring platform supported by steel pile foundation and circular sheet pile cofferdam constructed inside the polygonal ring platform.

Three precast circular segments, 1.2 m in height each, were assembled on the platform to form the shaft with a combined height of 3.6 m. The segments were tied together. Eight brackets were installed at equal spacing circumferentially on the exterior surface of the top segment.

The screw jacks and hydraulic jacks were stroked down respectively until the top of the assembled segments was 1.0 to 1.5 m above the platform level. Then another three segments of precast shaft with eight brackets were assembled on the previous one. The process is repeated until the desired bottom elevation is reached.

3. Diffuser Pipe and Risers

The diffuser pipe was a submarine pipeline with an inside diameter of 2.60 m extending about 613.50 m from the offshore shaft. The top of the pipe is 1.20 m below the seabed The optimal length of each diffuser segment for construction is 60 m. Pile supports of each diffuser segment are 12.70 m away from the segment’s ends to have zero end rotation.

The diffuser is designed for construction stage where seabed is excavated for diffuser installation and service stage where excavated soil is backfilled. Current and wave forces are included. Supporting piles are idealized as pinned supports. The resulting thickness (12 mm) is added by sacrificial thickness of 3 mm from 30 year corrosion. During the first 50 years, corrosion of the diffuser is protected by cathodic protection system.

The segments were connected to each other by clamping split steel collars as a hinged connection. A trench was prepared before commencing pile driving at the designed coordinates. Prefabricated steel crossbeam was connected to the piles at the designed elevation with steel straps connecting the diffuser pipe to the crossbeam. Cathodic protection anodes were connected by divers. Connecting the diffuser pipe to the offshore shaft had to be done after the completion of tunnel and the retrieving of the TBM. A gap of 9.50 m between the shaft and the diffuser pipe was provided to accommodate this construction sequence. Before connecting the diffuser pipe to the offshore shaft, hydrostatic pressure at the exterior and interior of the shaft had to be equalized by filling shaft and tunnel with water.