2nd International Conference on Civil Infrastructure and Construction (CIC 2023)
5-8 February, 2023 Qatar University, Doha, Qatar

Diffuser Bed Construction Challenges on the Musaimeer Pump Station and Outfall Project

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Abstract

Musaimeer Pump Station and Outfall project (MPSO) is a strategically important drainage asset initiated, developed, and completed by Ashghal in 2022. This project accommodates ground and storm water received from the drainage networks of 270 km2 of urban areas in southern Doha, along with storm protection for four soccer stadiums used during the FIFA 2022 World Cup. The key elements of this project were a pump station with a capacity of 19.7 m^3 / s, one of the longest ground and storm water tunnels in the world with a total length of 10.2 km and the diffuser bed structure measuring 194 m x 40 m. The diffuser bed structure is connected to the outfall tunnel by a riser shaft and is the structure used to disperse the ground and storm water in a controlled manner and in accordance with environmental standards. This technical paper will detail the entire process from dredging and material stockpiling, riser shaft drilling and construction, diffuser bed fabrication onshore, transportation to final location, installation on the sea floor, backfilling and protection works and finally commissioning of the entire project.

Keywords: Diffuser bed structure; Riser shaft; Outfall tunnel

1 Introduction

The Musaimeer Pumping Station project is governed by the Qatar Construction Specifications (QCS, 2014). The Public Works Authority (PWA) have engaged in two contracts. Firstly Mott MacDonald Ltd., which is the Project Management Consultant (PMC) company, and HBK-PORR JV, which is the Design, Build, Operation and Maintain Contractor for the construction of the MPSO Project, which is the final receiver of the upstream drainage system and located at the end of the Abu Hamour Tunnel, immediately south of the Hamad International Airport (HIA). The outfall tunnel extends from the pump station, 10.2 km offshore discharging the flows into the Arabian Gulf. The discharging will be performed through a vertical riser shaft and a marine outfall diffuser field. Figure 1 shows the project location.

Fig. 1: Project Location

2 Design

The marine diffuser field structure is shown in Fig. 2. The central manifold is located directly on top of the riser shaft and is a concrete structure measuring 4 m x 4 m x 4 m and weighing 120 Tons. Connected the main manifold are 6 radial arm structures which either directly connect to the manifold or are connect by short secondary manifolds. Each arm is 147 m long and is separated from the adjacent arm by 20 m. This makes the entire structure outline 294 m x 40 m. The secondary manifolds and 6 arms are manufacture out of High-Density Polyethylene (HDPE) pipe and are of various diameters 2000,1400, 1200 and 710 mm to ensure an even flow throughout the various arms under varying flow rates from the pump station. The discharge from the structure to the sea is via 84 duck bill valves located equal spacing along the 6-arm structure.

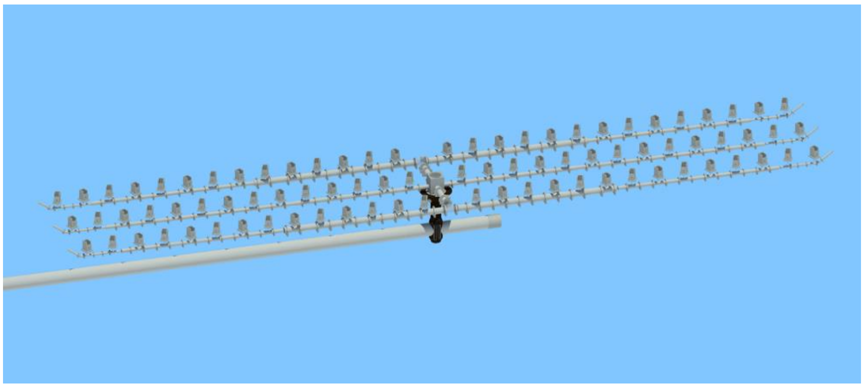


Fig. 2: Marine diffuser field structure, riser shaft and TBM outfall tunnel

3 Derdging and Material Stockpiling

The dredging was carried out by a Cutter Suction Dreger (CDS), which consists of a cutter mechanism mounted upon a barge and is capable of being lowered and raised from the seabed allowing excavation of the diffuser field pocket, which was 300 m long, 60 m wide and 5 m deep. The total matter excavated was 65,000 m³. The excavated material was placed in a stockpile located 50 m away and transportation of material was via a floating discharge pipe. All excavated material was later reused for back filling purposes, significantly reducing the environmental impact of the marine works

4 Riser Shaft Construction

The riser shaft is the structure which connects the TBM outfall tunnel to the marine diffuser bed. The invert of the outfall tunnel is 14.5 m below the seabed and the depth of the sea at this location is 15.5 m. The specialist Contractor engaged for the section of the work by HBK PORR JV was MIC

(W.L.L). The first stage in the construction is carried out by a dredger which on average removes 2.5 m of the loose sediments located on the seabed. Near the riser shaft a further 2 m is excavated to ensure competent strata is exposed which will improve the drilling operation required to construct the riser shaft.

Fig. 3

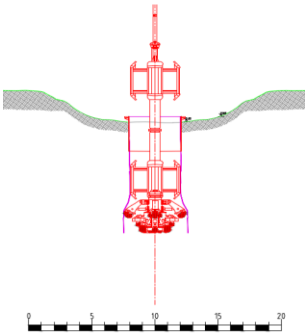


Fig. 4

Fig. 5

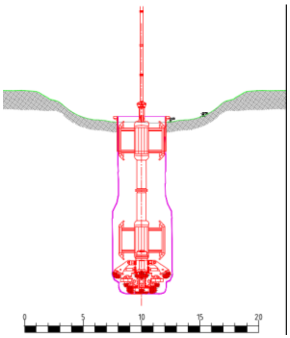


Fig. 6

With the dredging complete the next stage of the construction is carried out from a jack-up rig which is located direct adjacent to the centre line of the riser shaft. A cantilever frame is then installed to the side of the jack-up rig, this is the location the drilling equipment will be installed. The drilling rig or Bottom Hole Assembly (BHA) is shown in Figure 3. The BHA is lowered down to the correct location and commences to drill the rise shaft, shown in Figure 4 and 5. The BHA can dill various diameter holes from 4 to 5.3 m by use of extending hydraulically activated arms to suit the desired diameter of shaft. In this case the first section was drilled at 4 m diameter and then the arms are extended out, as shown in Figure 6 to the 5.3 m settings. The 5.3 m section is the location through which the TBM will excavate, giving a clearance of 500 mm each side of the TBM, which has an outer diameter of 4. 3 m.

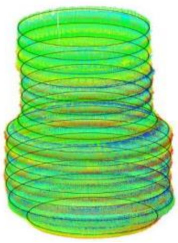


Fig. 7

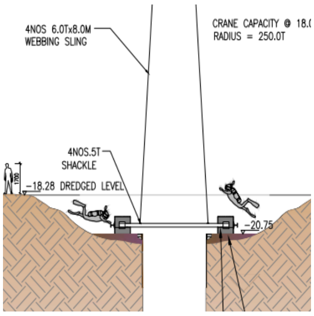


Fig. 8

Fig. 9

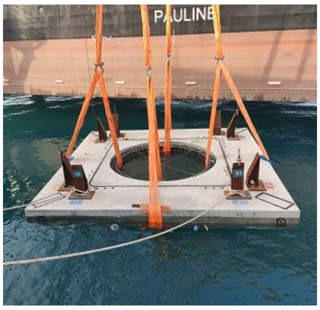
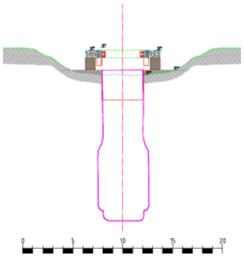
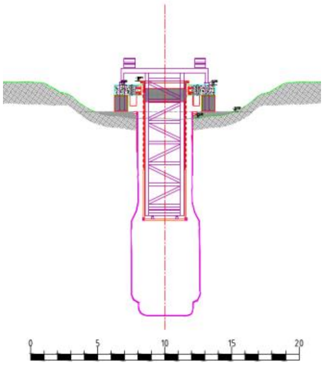


Fig. 10

On completion of the riser shaft drilling the BHA is then removed, and a three-dimensional survey carried out to determine the exact dimensions and position of the riser shaft, shown in Figure 7. The next stage shown in Figure 8 is to install a steel casing into the top 3 m of the riser shaft, to provide stability and prevent collapsing of the shaft inwards. Four Concrete manifold foundation blocks are then positioned and levelled into the correct position and connected to the steel casing, these activities are shown in Figures 8 and 9. A manifold concrete base slab (Figure 10) is then positioned on top manifold foundation blocks as shown in Figure 11.





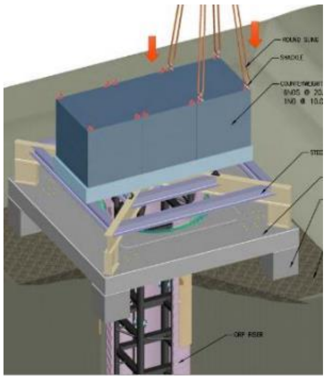
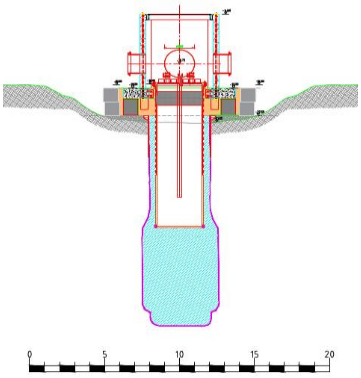
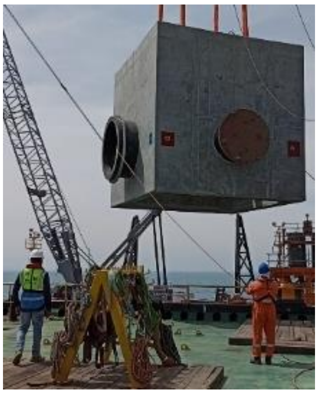


Fig. 11 **Fig. 12** **Fig. 13** **Fig. 14**

The riser shaft internal lining protects downwards from the base of the concrete manifold to 500 mm above the TBM outfall tunnel and is made from Glass Reinforced Plastic (GRP). This is a cylindrical shape with a fixed end at the lowest end and a removable flange at the other end. A temporary steel support frame is installed within the GRP cylinder, refer to Figure 12. The GRP cylinder and steel frame are then installed into the riser shaft as shown in Figure 13 and positioned centrally within the riser haft and connected to the base slab. At this point the riser shaft is still full of sea water. Figure 14 shows the temporary Kentledge, which is then placed on top of the whole structure to prevent uplift during the grout placement.

The void between the GRP cylinder and the whole of the lower portion is then installed with a grout mixture, which fills the void in a controlled manner, slowly displacing the seawater. The grouting is shown by the blue colour in Figure 15.





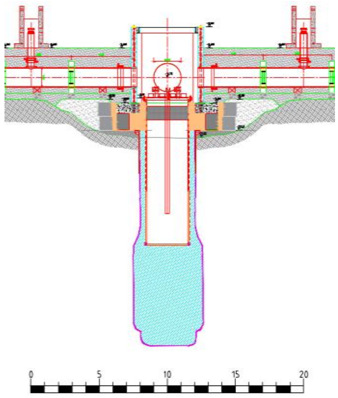


Fig. 15 **Fig. 16** **Fig. 17**

When the grout has cured, the kentledge is removed along with the internal steel frame and the upper flanged is secured and sealed to the top of the GRP cylinder. Both top and bottom ends of the GRP cylinder have a series of installed valves which allow venting of air or water. The upper valves are then used in connection with compressed air to remove all the seawater within the GRP cylinder and leave only air within the GRP cylinder.

The central manifold which collects the combined ground and storm water from the outfall tunnel and then distributed evenly to the diffuser structure, was constructed on shore, and weighed 120 tons. The concrete manifold is shown in Figure 16 and is then lowered and positioned on top of the riser shaft and connected to the manifold base slab as shown in Figure 17.

In due course all the diffuser field structure is connected piece by piece to the central manifold until the full diffuser bed structure is installed and covered with back fill material and then a final layer of scour protection installed and covering the entire diffuser bed structure, this shown in Figure 17. At this point the riser shaft structure is ready to receive the TBM constructing the outfall tunnel.

5 Onshore Fabrication

All the major components of the offshore diffuser bed structure were manufactured at two onshore locations in the Doha area. The major components include pipe work in

- HDPE Pipe and Connections.
- Concrete Manifold.
- Concrete Protection box.
- Concrete collars.

The main fabrication site was located a Milaha port south of Wakra. In this site all the above except the concrete collars were fabricated and assembled. These are shown in Figure 18. To ensure an equal flow through the entire length of each of the six arms each start at 2000 mm diameter and then reduced to 1400 mm and then finally 1200 mm.

Milaha Port site | HDPE pipework being assembled | HDPE pipework transition

Fig. 18: Onshore fabrication works

6 Transportation

When each section of the diffuser field pipe structure was complete it was then assembled on shore, the end is than capped with a blank flange to ensure water does not end the inside of the pipe. The pipe is then launched onto the sea, the structure then towed out to the diffuser bed location. Figure 19 shows a pipe structure in process of being towed out to the diffuser bed location. The Concrete manifold was transported separately by barge.

On-shore to Off-shore launching | Pipe section ready for towing | Pipe section with concrete collars

Fig. 19: Launching of pipe elements from onshore to the sea

7 Installation of Disfusser Structure

After the various elements of the diffuser structure have been transported to the final location, they are anchored and stored ready for installation. The main barge is positioned in line with the final seabed location. The individual sections are then manoeuvred into position and then the central manifold sections are lowered first using a barge mounted crane. Final under water positioning is carried out by specialist divers. The first sections installed are the ones which connect to the central manifold, then followed by sections moving out from the central manifold. The pipe section is manoeuvred into position and buoyancy aids attached the full length of the pipe. Water acting as ballast is slow allowed to enter the pipe section resulting in the structure submerging in a controlled manner to the seabed, refer to figure 20. The final positioning is carried out by specialist divers and secured to the already installed elements.

Central manifold — Pipe section with buoyancy aids — Submerging the pipe

Fig. 20: Launching of pipe elements from onshore to the sea

The whole structure is then assembled section by section in this manner until the full diffuser arrangement is completed.

8 Backfilling and Scour Protection

On completion of the diffuser bed structure the next sequence of work is to back fill the structure for stability and then install scour protection for the whole installation along with specially designed concrete protection boxes for each of the 84 duck bill valves. Back filling activity is shown in Figure 21

Backfilling barge and excavator — Reused back filling material — Backfilling in process

Fig. 21: Backfilling of the diffuser bed structure

9 Connection to Outfall Tunnel

The programme for the overall project required the diffuser bed structure to be completed prior to the arrival of the TBM, this was achieved. The TBM excavated to within 5 m of the riser shaft shown in Figure 23 and depressurizes the cutter head and monitors the situation for any water inflow over 8 hours. This was to test if the riser shaft was watertight to ensure the future connection works to be carried out in a safe manner. In this case there was no water inflow and thus the TBM excavates through the lower portion of the riser shaft and stops 25 m beyond the riser shaft as shown in Figure 23.

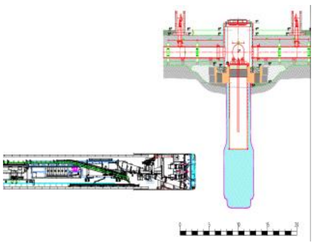


Fig. 22

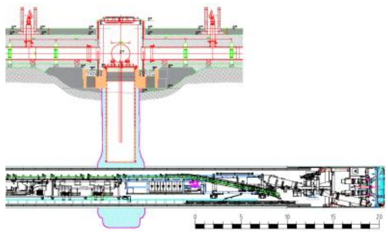


Fig. 23

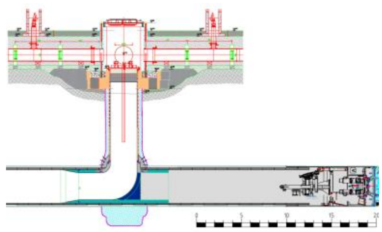


Fig. 24

The TBM and associated plant and equipment is then dismantled and removed back through the outfall tunnel and at the pump station location removed to the surface. The 25 m tunnel beyond the riser shaft is filled with concrete, refer to Figure 14, and then there follows very intricate and complex series of construction activities requiring precise logistical planning and execution to complete the connection of the outfall tunnel to the riser shaft and installation of the permanent works all of which is carried out 10.2 km offshore.

10 Commissioning

With the connection to the outfall tunnel complete the final element of the work is to fill the entire system with water from the inland tunnels. This is a slow process in which the filling is controlled to ensure all the air is removed from the system and the system is then ready for operation. This process went to plan and the project was commission on the due date and is now in full time operation.

11 Conclusion

This was the first of three possible outfall projects planned by Ashghal for the long-term management of rising ground water level and storm events, which will bring significant benefits to the population of Doha and surround areas. There were many lessons learned from the project and these have all been categorized and been considered by Ashghal for future projects. The project was a significant success and appreciation is extended to all parties involved in coming together and working to achieve the successful completion of this project.

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Cite as: Peach G., Fernandez H.V. & Al-Marri S.Z., "Diffuser Bed Construction Challenges on the Musaimeer Pump Station and Outfall Project", *The 2nd International Conference on Civil Infrastructure and Construction (CIC 2023)*, Doha, Qatar, 5-8 February 2023, DOI: https://doi.org/10.29117/cic.2023.0154