Sibenik outfall project – an attempt to change final user's role in outfall projects

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Summary

Construction of the Sibenik submarine outfall (DN 1200 mm, L=5.000 m, D=61.0 m) within the framework of the Sibenik Bay Sanitation Project, which took place in the early spring 2004, was seen as an opportunity to assemble a team of professionals with the main goal to provide not only a combination of local and international expertise, but to actively involve and support outfall managers before, during and after construction of such a demanding installation. This kind of approach, quite innovative in local circumstances, enabled the outfall managers to timely spot all important system features and to become familiar with the structure, its versatility (long flexible HDPE pipe strings with minimum number of joints), contractor's and consultant's skillfulness and methods of work, all to the benefit of all stakeholders involved.

Keywords:
depth outfall, long HDPE pipe strings, design optimization, Final User-oriented consultancy

Introduction

Sibenik submarine outfall (DN 1200 mm, L=5.000 m, D=61.0 m) represents the biggest outfall ever built in the Eastern Adriatic region (Figure 1). Following the track of successful

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application of long HDPE pipe string concept applied in the neighboring area of Split, the decision has been made to delegate realization of the project to the team of professionals who had previously demonstrated all advantages of both HDPE pipes delivered in long strings and of combination of local and international expertise in such class of deep sea outfall projects.

Figure 1: Geographical location of the Sibenik outfall

However, based on the fact that outfall managers often lack a real practical knowledge on the behavior and of big-diameter long outfalls and typical problems related to their operation and maintenance, the Final User was this time encouraged by the Consultants to play more active role right from the early stages of project implementation. This kind of approach, quite innovative in local circumstances and very appreciated by governmental institutions both from the pipe supplier's and the Final User's country, resulted in a number of technical improvements and benefits for all parties involved. One of them, which deserves to be particularly underlined, consists in the fact that unlike traditional approach, the Client has been given the unique opportunity to timely spot the features and weak points (if any) of both the be-born and real system.

1. **Outfall final design review**

Baseline solution of the Sibenik outfall was proposed in the Sibenik Outfall Final Design. Main features of that solution are summarized in Table 1.
Expected hydraulic load:

<table>
<thead>
<tr>
<th>stage</th>
<th>l/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWF Q\text{max}</td>
<td>913.0</td>
</tr>
<tr>
<td>DWF Q\text{max}</td>
<td>575.0</td>
</tr>
<tr>
<td>stage II</td>
<td></td>
</tr>
<tr>
<td>RWF Q\text{max}</td>
<td>1533.0</td>
</tr>
<tr>
<td>DWF Q\text{max}</td>
<td>1259.6</td>
</tr>
</tbody>
</table>

Outfall length (incl. diffuser) 5000 m
Outfall pipe material HDPE (high density polyethylene)
Pipe outer diameter, SDR OD =1200 mm, SDR 26
Discharge depth -60 m
Wastewater type preliminarily treated urban wastewater (mixed sewerage system)
stage 1. mechanical treatment (minimum)
stage 2. biological treatment

Proposed pipeline delivery, assembly and launching

- **Alternative 1**: pipe delivery (by trucks) in 12 m long segments, butt-fusion welding, weighting of longer pipe strings and towing to the installation site.
- **Alternative 2**: delivery (towing from the factory to the site) of approx. 500 m long floating pipe strings, installation of concrete weights in sheltered location and towing of 1,5 km long pipe strings to the installation site.

Proposed trenched pipe solution (sea depth < -10.0 m below MWL)

Proposed trenched pipe solution (sea depth -10.0-15.0 m below MWL)
Proposed primary concrete weights design (weight in air 3150 kg, 480 pcs)

Proposed secondary concrete weights design (weight in air 9000 kg, 180 pcs)

Proposed distribution of primary and secondary concrete weights

<table>
<thead>
<tr>
<th>Chainage</th>
<th>Primary weight C-C distance</th>
<th>Secondary weight C-C distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+000.00-0+755.00</td>
<td>8 m</td>
<td>-</td>
</tr>
<tr>
<td>0+755.00-0+945.00</td>
<td>8 m</td>
<td>10 m</td>
</tr>
<tr>
<td>0+945.00-1+250.00</td>
<td>8 m</td>
<td>15 m</td>
</tr>
<tr>
<td>1+250.00-1+460.00</td>
<td>8 m</td>
<td>20 m</td>
</tr>
<tr>
<td>1+460.00-4+594.00</td>
<td>8 m</td>
<td>24 m</td>
</tr>
</tbody>
</table>

Proposed tapered diffuser design with alternating ports (27 round sharp-edged lateral diffuser openings D=18 cm)

Table 1: Sibenik outfall basic technical features as proposed by the Final Design
Review of the Sibenik Outfall Final Design resulted in the following conclusions, suggestions and recommendations [1], eventually accepted by all parties involved:

- Reviewed Final Design represents a solid basis for further steps of design documentation preparation (Detailed Design and Sinking Procedure).
- With respect to proposed pipe delivery alternatives, the alternative with long pipe string is preferable as it results in very few joints and no land based work site.
- Proposed trenched pipe solution is recommended for shallow trench sections only. In deeper trench, the design can be simplified to avoid execution of underwater concrete works. Designed solution for protective embankment in shallow water is lacking crown protection layer.
- Proposed weighting concept with primary and secondary weights would complicate the installation and would introduce a bulk of post-installation work. Secondary weights would not be firmly tightened to the pipe and could either be detached from the pipe or damage it if they loose supports.
- Primary weights can be the only loading on the pipeline, sufficient to guarantee the outfall stability in all expected operating conditions. Firm and uniform grip force can be obtained by using rubber compensators with bolt sets.
- Proposed weighting degree in deep water (40-50%) is definitely oversized. Instead, approx. 20 % loading is considered appropriate for deep water. In the region between 15-25 m depth, where pipe is still exposed to wave and current forces, higher weighting degrees (e.g. 40 to 30 %) can be recommended.
- Recommended weighting degree can be obtained by changing C-C distance between primary weights.
- Rectangular shape of concrete weights can be recommended as they provide higher friction and better resistance to sliding/rotation at inclined sea bottom.
- Proposed diffuser port diameter is oversized and can be reduced to ensure better jet hydraulics and higher initial mixing rates in the near-field zone around the diffuser. Staged drilling of diffuser ports is recommended as well. Instead of eccentric reducers, concentric reducer design can be recommended as it would not require submerging in a pre-determined position.
- In intermittent discharge conditions, return flow and salt water intrusions can be prevented by installing duckbill valves on the ports. This measure is particularly important in early stages of outfall operation when outfall hydraulics could be seriously compromised by the saline wedge in the diffuser pipe.
- Deaeration facility is required to ensure elimination of the air from the outfall. In early stages of outfall operation wastewater residence time will be prolonged, implying the possibility to have additional problems with gas accumulation in the pipeline.
- Major stress in the pipe will be encountered during pipe submersion in S-shaped configuration. All other calculated stresses in operational phase are far less important. It is very important to prepare detailed Installation Design and Sinking Procedure that will ensure continuity of sinking process with no interruptions that could cause limit pipe curvatures and/or buckling of the pipe before landing on the sea floor.
2. **Installation design**

On the basis of recommendations in [1], the Installation Design (based on well known method of S-lay technique shown in Figure 2) was prepared. Two installation scenarios were analyzed:
A: one continuous submersion of the whole pipeline and
B: submersion divided in 3 sequences with 2 offshore intermediate tie-ins.

![S-lay installation of flexible pipelines](image)

**Figure 2: S-lay installation of flexible pipelines**

Following topics were covered by [2]:
- Pipeline positioning/pulling/hold-back arrangement
- Inlet water flow versus hydrostatic buckling control
- Regulation of internal air pressure in the pipeline/ sinking speed control
- Longitudinal pulling force/ S-curve bending radii control
- Computer simulation of the S-curve configuration during the submersion
- Termination end diving/ landing on seabed
- Recovery of pipeline ends
- Offshore intermediate tie-ins
- Diffuser installation
- Lists of resources and preparatory work required
- Work window/Weather limitation/Contingency plan
- Step-by-step actions
- Pressure diagrams as work tool for controlling the sinking speed

The planned anchor block intervals were differentiated along the pipeline. Planned pipe section ID/Anchor Block distribution is shown in Table 2:
In addition to all above topics related to pipe installation, tailored communication set-up (Figure 3) was devised and elaborated in [2].

### Table 2: Planned Sibenik outfall pipe section ID/Anchor Block distribution

<table>
<thead>
<tr>
<th>SECTION</th>
<th>END ID</th>
<th>CHAINAGE FROM</th>
<th>CHAINAGE TO</th>
<th>ACC. DIST.</th>
<th>BLOCK DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>I/000</td>
<td>0</td>
<td>527</td>
<td>527,0</td>
<td>LENGTH: 12,0 # PCS: 44</td>
</tr>
<tr>
<td>II</td>
<td>II/527</td>
<td>527</td>
<td>760</td>
<td>760,0</td>
<td>233,0 # PCS: 19</td>
</tr>
<tr>
<td>II</td>
<td>II/1058</td>
<td>760</td>
<td>1058</td>
<td>1058,0</td>
<td>298,0 # PCS: 75</td>
</tr>
<tr>
<td>III</td>
<td>III/1058</td>
<td>1058</td>
<td>1250</td>
<td>1250,0</td>
<td>192,0 # PCS: 48</td>
</tr>
<tr>
<td>III</td>
<td>III/1250</td>
<td>1250</td>
<td>1460</td>
<td>1460,0</td>
<td>210,0 # PCS: 35</td>
</tr>
<tr>
<td>III</td>
<td>III/1460</td>
<td>1460</td>
<td>1589</td>
<td>1589,0</td>
<td>129,0 # PCS: 17</td>
</tr>
<tr>
<td>IV</td>
<td>IV/1589</td>
<td>1589</td>
<td>2120</td>
<td>2120,0</td>
<td>531,0 # PCS: 72</td>
</tr>
<tr>
<td>V</td>
<td>V/2120</td>
<td>2120</td>
<td>2642</td>
<td>2642,1</td>
<td>522,1 # PCS: 71</td>
</tr>
<tr>
<td>VI</td>
<td>VI/2642</td>
<td>2642</td>
<td>3162</td>
<td>3162,4</td>
<td>520,3 # PCS: 70</td>
</tr>
<tr>
<td>VII</td>
<td>VII/3162</td>
<td>3162</td>
<td>3690</td>
<td>3689,6</td>
<td>527,2 # PCS: 71</td>
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<tr>
<td>VIII</td>
<td>VIII/3690</td>
<td>3690</td>
<td>4216</td>
<td>4216,3</td>
<td>526,7 # PCS: 71</td>
</tr>
<tr>
<td>IX</td>
<td>IX/4216</td>
<td>4216</td>
<td>4741</td>
<td>4741,3</td>
<td>525,0 # PCS: 71</td>
</tr>
</tbody>
</table>

|     | total:    |              |             | 4741,3     | 664 |

Figure 3: Communication set-up for the Sibenik outfall installation
By using the ZENRISER computer-modeling program [3], sinking processes with different pulling forces were simulated. The results with 20 t pulling force are shown in Figure 4.

Figure 4: Simulation of sinking process with 20-t pulling force
3. **Sinking of the pipeline (scenario B)**

In accordance with the scenario B, the installation was carried out in three independent operations. First sequence, including tow-out and assembly of three pipe sections, rigging of landfall holdback, positioning and submersion to the designed position was performed in May 2004. (Figure 5).

![Figure 5: Positioning and sinking of the first assembled string of the Sibenik outfall](image)

4. **Operation and maintenance issues**

In addition to the whole range of consultancy services that typically accompany this type of outfall projects, the Final User has been timely provided with the O&M manual [4], comprising all relevant topics related to big-diameter outfall operation and maintenance issues, with special reference to the outfall in concern. The manual contents covered the following topics:

- Identification of main potential operational problems
- Preventative measures to avoid/minimize operational problems
- Outfall inspections
- Outfall land section hydraulics – free surface flow conditions
- Outfall land section hydraulics – pressure flow conditions
- Outfall submarine section hydraulics – pressure flow conditions
- Diffuser hydraulics
- Development of pipeline repair procedures
- List of recommended spare parts
- Procedure and action in emergency situations
- Outfall performance and sea state monitoring
- Forms

In particular, following issues have been analyzed in detail in [4]:

- partial pipe clogging by deposits from wastewater
- air entrainment problems
- air (gas) production as a result of biological decomposition of wastewater
- hydraulic jumps and water hammer, transient underpressures
- intermittent discharge regime hydraulics
- movements of the pipeline due to waves, currents, sand scouring and air accumulation
• saline water intrusion
• effectiveness of a multiport diffuser, diffuser blockage
• marine life growth
• sediment deposition in low flow periods
• entrance of marine organisms and plants into the outfall
• damages in accidental situations
• preventative measures to avoid/minimize operational problems
• outfall inspections
• regular maintenance, general inspection, detailed (close visual) inspections, inspection of pipeline interior (CCTV inspection)
• local repair of holes or cuts, underwater repair of pipe section, additional ballasting of the pipeline with spare blocks
• deaeration of trapped air/gas pockets from the pipeline
• list of recommended spare parts
• procedure and action in emergency situations
• monitoring of baseline sea conditions, pre-discharge monitoring at the discharge site, post-discharge monitoring, beach monitoring, recommended locations and frequency of sampling
• visual control log
• cathodic potential log

Eventually, the importance of education on the outfall operation & maintenance issues which, after successful installation become crucial for overall success of the Sibenik Bay Sanitation Project, has been fully recognized by all participants to the Education & Training seminar, organized at the Final User's premises in parallel to the outfall construction.

5. **Conclusions**

Client-oriented consultancy in outfall projects should not include only a high level of professionalism in offering technical expertise, which very often remains a "black box service" for typical outfall managers.

Being convinced that outfalls are not just a simple pipelines aimed to transport wastewater to the discharge site, maximum effort has been made during realization of the Sibenik outfall project to change traditional position of the Client and transform it into the active participant's role who became introduced timely in all important aspects of the project realization and problems encountered before the outfall commissioning.

By doing so, it seemed legitimate to presume that the Client's level of knowledge and overall responsibility would be significantly higher than usual, to the benefit of all parties involved in the project.

6. **Acknowledgments**

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References

[2] HDPE pipeline installation procedure, Veidekke ASA