Pipeline Design Criteria for Intake and Outfall system

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1 SCOPE

This report, with other design bases and specifications referred to in this document, covers the criteria of the pipeline design for intake and outfall systems. All installation design data should be referred to this document. Hence, the document must be kept “live” until the end of the design activity in order to capture any changes in the design parameters during the course of the basic/detail design and installation of pipeline.

2 DESCRIPTION

2.1 Codes and Standards

The following standards shall be considered for the design and construction/installation of submarine pipelines.

- DNV-RP-F109. (Det Norske Veritas), On-Bottom Stability Design of Submarine Pipelines
- DNV-RP-C205. (Det Norske Veritas) Environmental Conditions and Environmental Loads
- API 2A-WSD Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-Working Stress Design
- API RP-1111 Design, Construction, Operation, _ Maintenance of Offshore. Hydrocarbon Pipelines
- BS 8010 Code of Practice for Pipelines Part 3. Pipelines Sub Sea: Design, Construction and Installation
- AWWA American Water Works Associations
- CEM 2006 Coastal Engineering Manual
- DIN 2501 Deutsches Institute fur Normung, Steel Flanges
- DIN 8075, Polyethylene Pipes General Quality Requirements and Testing
- DIN 16961-1 Thermoplastics Pipes and Fittings with Profiled Wall and Smooth Pipe Inside - Part 1: Dimensions
- DIN EN 13476-1 Plastics piping systems for non-pressure underground drainage and sewerage - Structured-wall piping systems of unplasticized poly (vinylpolypropylene (PP) and polyethylene (PE)
- ASTM F 894 Standard Specifications for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe
- ISO 9969 Thermoplastics pipes - Determination of ring stiffness
- EN 1610 Construction and testing of drains and sewers
- DVS 2207 Welding of thermoplastics - Heated tool welding of pipes, pipeline components and sheets made of PE-HD
- EM 1110-2-2906 U.S. Army Corps of Engineers, Design of Pile Foundations

2.2 Computer Software

The computer software, which will be used during basic, detail design and Installation, are as follows:

- ABAQUS
- SAP2000
- AUTOCAD
- Autodesk Land
- MATHCAD
- MICROSOFT OFFICE

2.3 System of Units

International SI unites will be used throughout the design process unless otherwise specified.

2.4 Coordinate System

The location of the works shall have grid co-ordinates (in meters) for Universal Transverse Mercator (UTM).

2.5 Service Life

The design service life of the pipeline system is considered to be 50 years.

2.6 Pipeline Material

The pipe material and property will be determined by considering the project conditions.The section of pipes should satisfy hydraulic requirements and suffers the pressure of soil and rocky protection material. Internal Anti-Corrosion Coating

The steel pipeline will be protected from internal corrosion by means of an internally applied coating supplemented with a Cathodic Protection (CP) system. The internal corrosion coating shall be as per specifications.

2.7 External Anti-Corrosion Coating

The steel pipeline will be protected from external corrosion by means of an externally applied inert coating such as polyurethane. The polyethylene pipes do not require any anti- corrosion system.

2.8 Chlorination System

The use of hypo chloride for controlling the biological fouling in the seawater intake system is essential. At sea water intakes in head of inlet pipe, continuous dosing is considered for controlling the mollusks, algae, slime and weed. They constrict the flow of the sea water in the intake pipe. It also prevents marine gross deposition in the pipeline which is the most troublesome to remove. To avoid biological organisms from getting used to hypo chloride, a shock injection system has been considered as well.

Continuous dosing and shock injection hypo chloride shall be specified by the client. The hypo chloride pipes are considered to be connected internally or externally to the main pipelines. It is referred to external installation chlorination pipes due to periodic inspection, repair and maintenance of these pipes, assurance of no leaking and keeping the chlorination operation safe. The local experiences also show that the external installation of chlorination pipes is easier.

2.9 Geotechnical Data

Design criteria and Geotechnical data are presented at "Geotechnical design criteria for intake and outfall system".

2.10 Loads and Load Conditions

2.10.1 Loads Type

The following load types have been considered:

- Self-weight (including weight of pipe and coatings, attachments, contents);
- Buoyancy effects;
- Internal fluid loads (pressure, inertial effects);
- External hydrostatic pressure;
- Fabrication and Installation forces(such as handling forces, tow loads, applied lay stress, internal pressure, and trenching forces);
- Loads due to changes of pressure and temperature;
- Environmental loads (due to wind, wave, currents, earthquake, etc.);
- Seabed stability settlement and pipeline movement;
- Accident loads (such as ship moorings, fishnets, etc.)

2.10.2 Load Conditions

Different loading conditions have been considered in order to demonstrate suitability of the design. Load conditions and loads type in each condition are presented in Table 1.

Table 1 Load Conditions

Condition / Load Type		Construction	Installation		Operation	
			Floating	Laying	Normal	Earthquake
Self-weight	Weight of pipe and coating	x	x	x	x	x
	Weight of attachment	x	x	x	x	x
	Weight of contents		x	x	x	x
Buoyancy			x		x	x
Internal fluid	Pressure		x	x	x	x
	Inertial Effects		x	x	x	x
Temperature					x	

Environmental	Wind		x			
	Wave		x	x	x	x
	Currents		x	x	x	x
	Earthquake					x
Deformation				x		
Backfilling					x	x

3 PIPELINE HYDRULIC DESIGN METHODOLOGY

In order to supply water for desalination facilities, seawater is the only source of water supply. The water should have volumetric flow rate 330000 m^3/day for two pipelines in normal condition; also each pipeline should be designed for 70 percent of total flow rate in emergency condition. Therefore each pipeline will be designed for the flow rate of 231000 m^3/day. In this section, the methodology of pipeline hydraulic calculation is presented.

The design of pipelines as one of the most commonplace close conduit water conveyance systems strongly depends on the hydraulic calculations. Hydraulic calculations include determination of head at the ends of the pipeline and head loss calculation along the entrance and the exit of the system. Two main equations applied for hydraulic calculations are Continuity and Bernoulli equations. In this project, water head at sea side of the pipeline is one of the input data. Then determination of the water head at the land side end of the pipeline based on the mentioned equations and encountered head losses is the main objective of the hydraulic calculation. Head loss in a pipeline hydraulic system includes friction and minor losses which are called h_f and $h_{L\ minor}$ hereafter respectively.

$$\frac{P_1}{\gamma}+\frac{V_1^{\,2}}{2g}+z_1=\frac{P_2}{\gamma}+\frac{V_2^{\,2}}{2g}+z_2+h_L$$

$$h_L=h_f+h_{L\,\mathrm{min}or}$$

3.1 Head Losses

3.1.1 Frictional losses

For turbulent flow (Reynolds number, above 4000), the friction factor, f, is dependent on two factors, the Reynolds number and pipe inner surface roughness. The friction factor may be chosen from Figure 1, the Moody Diagram, which can be used for various pipe materials and sizes. In the Moody Diagram, relative roughness, ε/D, is used. The friction factor may then be determined using the Colebrook formula. The friction factor can also be read from the Moody Diagram with enough accuracy for calculation.

The Colebrook formula is:

$$\frac{1}{\sqrt{f}}=-2\cdot\log_{10}\left[\frac{2.51}{R_e\sqrt{f}}+\frac{\varepsilon/D}{3.71}\right]$$

With:

ε : absolute roughness[m]

Re : Reynolds number($\frac{VD}{\nu}$)

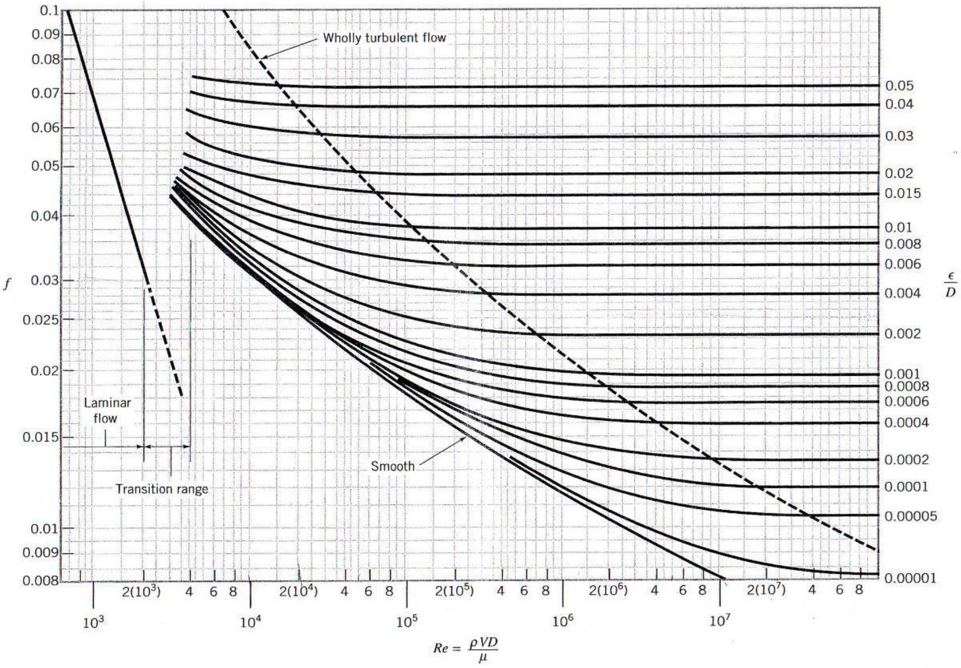

Figure 1 Moody Diagram

The surface absolute roughness of the pipes can be taken from the acceptable standards in the current project (DNV-RP-C205).

For a new HDPE pipe, the absolute roughness value can be as low as 0.05 mm but this is only of theoretical interest. The surface absolute roughness of HDPE pipes can be taken from Table 2 (Pipelife, Technical Catalogue for Submarine Installations of Polyethylene Pipes).

Table 2 Design Values for Equivalent Roughness (ε)

Type of water	Type of PE-pipeline		
	Intake	Transit	Outlet
Potable	2 mm	0.25 mm	-
Sewage	-	0.50 mm	1 mm

3.1.2 Minor Losses

Energy losses resulting from rapid changes in the direction or magnitude of the velocity are called minor losses, or local losses. Minor losses are usually expressed in terms of the kinetic energy and a coefficient, as illustrated by the equation

$$h_{L\,\mathrm{minor}} = K\frac{V^2}{2g}$$

In which K is the Loss Coefficient.

3.1.2.1 Entrance and outlet local head loss

The entrance local head loss depends on the inlet shape. Head loss coefficient in sharp edges is 0.5. The head loss coefficient at the outlet and the connection of pipeline and pump station basin is 1.0.

3.1.2.2 Local head loss in the intake tower screen

The pressure loss induced by the protective screens can be calculated on the basis of the recommendations of Press/Schroder:

$$K_{screen} = 1.45 - 0.45\frac{A_n}{A_g} - (\frac{A_n}{A_g})^2$$

With:

K_{screen} = Local head loss coefficient in screen

A_n = Net area of screen[m^2]

A_g = Gross area of screen

3.1.2.3 Local head loss of bends

Head loss coefficient of bends can be extracted from Table 3 (Water conveyance structures, M. K. Beirami, June 1999).

Table 3- Bend losses

Curvature angel / Bend type	10^0	30^0	45^0	60^0	90^0
Circular without curvature	0.03	0.11	0.24	0.50	1.1
Rectangular without curvature	0.04	0.14	0.30	0.60	1.40
Circular with curvature r = d	0.05	0.10	0.20	0.20	0.30
Circular with curvature r = 2d	0.03	0.08	0.10	0.10	0.20
Circular with curvature r = 3d	0.02	0.05	0.07	0.08	0.10

After calculation of these frictional and minor losses, the existing head at the both ends of the pipeline system will be compared to the calculated head losses and through a process of optimization, the best alternative will be obtained. It must be stated here that the longitudinal profile of the pipeline, which is usually in accordance with the natural topography of the region, is of great importance in calculating these head losses.

4 STRUCTURAL DESIGN CRITERIA AND METHODOLOGY

4.1 General

The procedure outlined in this section presents the criteria and methods of analysis that should be employed in the design process for steel and high density polyethylene type pipes.

4.2 Steel Pipe Structural Design Methodology

According to BS 8010, the design is based upon Allowable stress method (WSD).

Stress in the pipeline system should satisfy the following inequality:

$$\sigma_A < f_d \sigma_y$$

Where:

σ_A is the allowable stress, either hoop or equivalent;

f_d is the design factor;

σ_y is the specified minimum yield stress of pipe.

The design factors to be used in the design are displayed in Table 4.

Table 4 Design Factors f_d

Condition		Riser	Seabed
Hoop Stress		0.6	0.72
Equivalent Stress	Operation	0.72	0.96
	Construction & Installation	1.0	1.0

4.2.1 Wall Thickness Determination

Pipeline wall thickness shall initially be determined on the basis of pressure containment loads (internal and external) corrected for mill tolerance and subsequently checked against stability, buckling, expansion and environmental loading requirements. The calculated corrosion allowance will be added to the required wall thickness. Wall thickness calculations based on BS8010 Part 3 shall be performed. In the final selection of the required wall thickness, the following additional requirements should also be satisfied:

- The required submerged weight of the pipeline system should be achieved by the most economical combination of steel wall thickness;
- Different specified wall thickness in the same pipeline system should be minimized;
- The chosen wall thickness should be compatible with the expected installation method and practical pipe handling and;
- Pig ability of pipeline should be ensured.

The chosen wall thickness should avoid the need to use buckle arrestors to mitigate potential buckling propagation. Line pipe intended for use as field or factory formed bends shall have wall thicknesses and diameter which allow wall thinning and ovalisation during the bending process. The wall thickness of finished bends, taking into account wall thinning at the outer radius, should not be less than the design required for the wall thickness.

Due to the short overall pipe length, the selected pipeline wall thickness will be uniform throughout the length of the pipeline, to ease the installation and procurement procedure.

4.2.2 Stress Analysis of Steel Pipes

4.2.2.1 Hoop Stress

Hoop stress (σ_h) can be determined using the following equation when $(D_0/t < 20)$:

$$\sigma_h = (p_i - p_e)\frac{D_0}{2t}$$

Where:

p_i is the internal pressure

p_e is the external pressure

D_0 is the outside diameter of pipe

t is the minimum wall thickness of pipe subtracting any corrosion allowance.

4.2.2.2 Longitudinal Stress

The total longitudinal stress is chosen from the sum of the longitudinal stresses arising from pressure, temperature, weight, other sustained loading and occasional loadings. The pipeline is considered totally restrained when axial movement and bending resulting from temperature or pressure change occurred.

Shear Stress

The shear stress is calculated from the torque and shear force applied to the pipeline using the following equation:

$$\tau = \frac{1000T}{2Z} + \frac{2F_s}{A}$$

Where

τ is the shear stress;

T is the torque applied to the pipeline;

F_s is the shear force applied to the pipeline;

A is the cross-sectional area of pipe wall;

Z is the pipe section modulus.

4.2.2.3 Equivalent Stress

Equivalent stress is evaluated using the Von Mises' stress criterion:

$$\sigma_e = \left(\sigma_h^2 + \sigma_L^2 + \sigma_h\sigma_L + 3\tau^2\right)^{1/2}$$

Where

σ_e is the equivalent stress;

σ_h is the hoop stress;

σ_L is the longitudinal stress (combination of direct and bending stresses);

τ is the shear stress.

The nominal wall thickness could be employed in the evaluation of equivalent stress.

4.2.3 Buckling

4.2.3.1 Local Bucking

Local buckling of pipeline has been controlled by 3D FEM modeling of pipeline in critical location. As an alternative to control of local buckling, the following equation has been considered.

4.2.3.1.1 External Pressure

The characteristic value, P_C , required to cause collapse when the external pressure is acting alone, has been obtained from the following equations:

$$\left[\frac{P_c}{P_e}-1\right]\times\left[\left(\frac{P_c}{P_e}\right)^2-1\right]=2\frac{P_c}{P_y}\left(f_0\frac{D_0}{t_n}\right)$$

$$P_e=\frac{2E}{\left(1-\nu^2\right)}\left(\frac{t_n}{D_0}\right)^3$$

$$P_y=2\sigma_y\frac{t_n}{D_0}$$

$$f_0=\frac{D_{\max}-D_{\min}}{D_{\max}+D_{\min}}$$

Where

P_e is the critical pressure for an elastic circular tube;

P_y is the yield pressure;

f_0 is the initial ovalization of the pipe cross section;

P_c is the characteristic external pressure;

σ_y is the specified minimum yield stress of pipe wall material;

ν is the Poisson’s ratio for the pipe wall material;

t_n is the nominal wall thickness;

E is the Young’s modulus for pipe wall material;

$D_{\max}$ is the maximum outside diameter.

$D_{\min}$ is the minimum outside diameter.

D_0 is the outside diameter.

4.2.3.1.2 Bending

The characteristic bending moment value, M_c, required to cause buckling when bending moments are acting alone, has been obtained from the following equations:

$$\frac{M_c}{M_p} = 1 - .0024 \frac{D_0}{t_n}$$

And

$$M_p = (D_0 - t_n)^2 t_n \sigma_y$$

Where:

M_p is the fully plastic moment capacity of the pipe cross section.

4.2.3.1.3 Torsion

The characteristic value, τ_c, required to cause buckling when torsion is acting alone, has been obtained from the following equations:

$\tau_c / \tau_y = 0.542 \qquad for \quad \alpha_\tau < 1.5$

$\tau_c / \tau_y = 0.183 + 0.68(\alpha_\tau - 1.5)^{0.5} \qquad for \quad \alpha_\tau < 9$

$\tau_c / \tau_y = 1 \qquad for \quad \alpha_\tau > 9$

and

$$\tau_y = \sigma_y / \sqrt{3} \quad , \quad \alpha_\tau = \frac{E}{\tau_y} \left(\frac{t_n}{D_0} \right)^{\frac{3}{2}}$$

Where

τ_y is the yield shear stress

4.2.3.1.4 Combinations

The maximum external over pressure, P, in the presence of bending moment, M, when f_0 is less than 0.025 has been obtained from following equation:

$$\left(M / M_c \right)^n + \left(P / P_c \right) = 1$$

Where

$$n = 1 + 300 \frac{t_n}{D_0}$$

4.2.3.2 Propagation Buckling

The potential for pipeline to propagate local buckles is dependent on the external overpressure, P, and its relationships with the propagation pressure P_p. The external overpressure is given by the following equation:

$$P = P_0 - P_i$$

Where

P_0 is the external pressure;

P_i is the internal pressure.

The propagation pressure is given by the following equation:

$$P_p = 10.7 \sigma_y \left(t_n / D_0 \right)^{9/4}$$

If P is less than P_p then, even though the pipe may develop a local buckle, the buckle will not propagate.

If P is greater than or equal to P_p and a local buckle or local damage has occurred, then the pipeline is likely to undergo propagation buckling.

4.2.3.3 Global Buckling

Global buckling can occur in restrained pipe due to axial compressive forces, included by high operating temperatures and pressures. This can take the form of horizontal snaking of unburied or vertical upheaval of trenched or buried pipelines.

4.2.4 Ovalization

The total ovalization, f, of a pipe due to the combined effects of unidirectional bending and external pressure has been obtained from the following equation:

$$f = C_p \left[C_f \left(\frac{D_0}{t_n} \varepsilon_b \right)^2 + f_0 \right]$$

Where

C_f is $0.06\left[1 + D_0 / (120 t_n)\right]$

C_p is the magnification factor accounting for pressure effects $= 1 / (1 - P/P_e)$;

ε_b is the maximum bending strain;

f_0 is the initial ovalization.

4.3 HDPE Pipe Structural Design Methodology

According to DIN 8075, the design is based upon Allowable stress method (WSD).

Stress in the pipeline system should satisfy the following inequality:

$$\sigma_A < \sigma_S = \frac{MRS}{C}$$

Where:

σ_A is the required stress, either hoop or equivalent;

σ_S is the permissible design stress

C is the standard safety factor for water standard safety;

MRS is the minimum required strength of pipe (10 MPa).

The standard safety factors to be used in the design are displayed in Table 5.

Table 5 Standard Safety Factors C

Condition		C
Hoop Stress		1.6
Equivalent Stress	Operation	1.6
	Construction & Installation	1.25

4.3.1 Wall Thickness Determination

Pipeline wall thickness shall initially be determined on the basis of pressure containment loads (internal and external) corrected for mill tolerance and subsequently checked against stability, buckling, expansion and environmental loading requirements. The wall thickness which is needed for suffering the soil pressure and live loads is determined according to "Design of PE Piping Systems" [18]. In the final selection of the required wall thickness, the following additional requirements should also be satisfied:

- The required submerged weight of the pipeline system should be achieved by adding the most economical tools such as blast weight;
- Different specified wall thicknesses in the same pipeline system should be minimized;
- The chosen wall thickness should be compatible with the expected installation method and practical pipe handling;

Pipeline intended for use as field or factory formed bends shall have wall thicknesses which allow for wall thinning and ovalisation during the bending process.

4.3.2 Stress Evaluation

4.3.2.1 Hoop Stress

According to ISO, standard 161 part1 hoop stress (σ_h)can be determined using the following equation:

$$\sigma_h = \frac{P_i D_e}{2.s}$$

Where:

p_i is the working pressure (bar);

D_e is the average diameter of pipe (mm)

s is the wall thickness of pipe, here explicit only the water way wall(mm).

4.3.2.2 Longitudinal Stress

The total longitudinal stress is determined from the sum of the longitudinal stresses arising from pressure, temperature, weight, other sustained loading and occasional loadings. The pipeline is considered totally restrained when axial movement and bending resulting from temperature or pressure change occurred.

4.3.2.3 Equivalent Stress

Equivalent stress is evaluated using the Von Mises' stress criterion:

$$\sigma_e = \left(\sigma_h^2 + \sigma_L^2 + \sigma_h \sigma_L\right)^{1/2}$$

Where

σ_e is the equivalent stress;

σ_h is the hoop stress;

σ_L is the longitudinal stress (combination of direct and bending stresses);

The nominal wall thickness could be employed in the evaluation of equivalent stress.

4.3.3 Buckling

4.3.3.1 Constrained (Buried) Pipe Wall Buckling

Local buckling may be occurred due to soil pressure and live loads. It will be controlled according to Handbook of PE Pipe.

4.3.3.2 Buckling Due To External Pressure

The buckling forces could occur, if there exists a great difference between the inside and outside pressure of a pipe. The buckling capacity of a pipe structure is obtained from the following equation:

$$P_b = \frac{2E}{1-\alpha}\left(\frac{s_e}{D_m}\right)^3$$

Where

P_b is the buckling capacity of pipe(MPa);

α is the contraction coefficient(0.4);

E is the Young's modulus for pipe wall material(MPa);

D_m is the mean diameter of pipe $(D_i + s)$ (mm);

s_e is the equivalent solid wall thickness(mm)

4.3.3.3 Buckling Due To Bending

The minimum bending radius depends on the proportion of the pipe wall thickness to the diameter of the pipe. If the proportion is small, the minimum bending radius has to be considered with respect to the buckling. When the proportion increases, bending radius of the pipe wall has to be considered on a long-term basis. A maximum expansion of 2.5% (ε) should not be exceeded.

Formula for bending:

$$R_B = \frac{1}{0.28^{\bullet} s} \cdot \left(\frac{D_i + s}{2} \right)^2$$

Formula for expansion:

$$R_B = \frac{\left(\frac{D_i}{2} + s \right) \times 100}{\varepsilon}$$

Where

R_B is the bending radius (mm)

s is the wall thickness (for profiles the water wall thickness) (mm)

D_i is the internal diameter (mm)

ε is the peripheral strain (%)

Detailed FEM simulations could also be done for more assurance.

4.3.3.4 Global Buckling

Global buckling can occur in restrained pipe lines due to axial compressive forces that may be mobilized by high operating temperatures. This can take the form of horizontal snaking of unburied or vertical upheaval of trenched or buried pipelines.

5 IN-SITU PIPE DESIGN CRITERIA AND METHODOLOGY

5.1 Stability Analysis

The pipeline should be designed to be stable during construction and operation. The stability analysis should consider the following effects:

5.1.1 Submerged Weight

The submerged weight should be derived based on acceptable standards in the current project.

5.1.2 Ballast Weight

Ballast weights are used to anchor the pipeline properly on the seabed such as additional masses. The ballasting weights shall be designed based on the following considerations:

- Pipelines should remain on the water surface when filled with air during launching and transportation conditions.
- Pipelines should be properly stable on the trench after sinking and installation.

5.1.3 Hydrodynamic Forces and Lateral, Vertical On-Bottom Stability

Hydrodynamic forces should be determined in accordance with the acceptable standards in the current project (DNV-RP-F109, 2010).Pipelines are subjected to environmental loads; thus, it is necessary to consider and evaluate sufficiency of on-bottom stability in both lateral and vertical directions. Stability control and safety factor calculation should be carried out based on mentioned standard (DNV-RP-F109, 2010).

5.1.4 Soil Instability

Soil characteristics are according to Geotechnical Survey Interpretation for onshore and reports of offshore site investigations.
Soil instability may be initiated by seismic activity, wave action and seabed current, overloading due to weight of pipeline, deposition or scouring of seabed soil material, pipe trenching, pockmark and gaseous emission or slope failure. When a pipeline is routed through an area of potential soil instability, consideration should be given to stability enhancement methods.

5.1.5 Vertical Stability

When assessing the vertical stability of a pipeline, these parameters should be considered: the specific weight of the soil, the soil shears strength and seabed liquefaction. If sinking is likely to happen then the adverse effect on the pipeline should be considered. These include the following, overstressing of the pipeline due to uneven sinking and obstruction of future access to the pipe.

5.1.6 Stability Enhancement Methods

There are many different stability enhancement methods. So for this project, appropriate methods should be designed for stabilizing.

5.1.7 Trenching

Trenching may enhance pipeline stability by the following means:

- Trenching walls inhibiting sideways movement
- The trench tending to act as a sediment trap
- The trench side slopes providing some shelter from hydrodynamic forces

Analysis methods should consider these influences with allowance being made for uncertainties in predicting the actual trench profile.

5.1.8 Partial Burial

Partial burial enhances stability by the following means:

- Increased lateral soil restraint
- Reduction in hydrodynamic forces

5.1.9 Self Burial

Where knowledge of seabed condition and historical stability indicate that self burial to the required depth of cover is likely, the self burial may be utilized as a means of limiting artificial trenching or burial operations. The design should provide for artificial burial where burial is required and self burial does not occur.

5.2 Expansion Analysis

The expansion analysis will be performed for the operation case. The expansion analysis considers expansion due to the following:

- Thermal forces;
- End cap forces;
- Soil friction (contraction).

Following bases shall be applied for pipeline end expansion calculations.

- No axial restraint at the end of the pipeline;
- Maximum operating temperature and minimum installation temperature;
- Axial friction;
- Minimum content density;
- Upper bound temperature gradient compatible with the design operating conditions.

5.3 Spanning Analysis

Pipeline free span is usually resulted from an uneven seabed or localized seabed scouring. Pipeline would be laid in a submarine trench and backfilled in this project hence uneven sea bed or localized seabed scouring shall not be considered.

6 CONSTRUCTION ENGINEERING METHODOLOGY

6.1 Onshore Fabrication Site

6.1.1 Pipeline Fabrication

The onshore pipe stringing process generally involves three major steps:

- Welding & NDT of pipe joints into strings
- Application of field joint coating &infill
- Safe storage of pipe string ready for launch
- Pipeline strings on supports analysis

All construction work should be performed with equipment which has been proven reliable and suitable for field applications. Prequalification testing should be performed for all work, especially where previous experience is limited.

6.1.2 Welding & Testing

The selected type of welding equipment and the specified welding procedure is to be approved prior to any welding activities. The qualification test is to be also qualified prior to any commencement of construction welding. The qualification testing is to be carried out with the same or equivalent equipment as that to be used during construction. It is preferred to perform the tests at the proposed construction site under actual working conditions.

6.1.3 Pipe Handling

Handling analysis should be carried out for the pipe segment at any conditions:

6.2 Installation Analysis

6.2.1 Floating and Launching Analysis

For facilitating floating and launch operation, the whole pipeline is divided to several strings. Each pipe string will be launched separately toward the sea. The following aspects should be considered in floating and launching analysis:

- Pipeline buoyancy shall be controlled.
- Bottom level of fabrication yard shall be checked for floating condition.
- Stability of fabrication yard slopes shall be controlled for floating condition.
- Tidal levels shall be checked to allow for safe floatation.
- Floatation shall be scheduled to provide enough execution time.

6.2.2 Towing Analysis

Due to the nature of the project, surface tow methodology is the preferred choice of installation technique, as it offers the following advantages:

- Pulling forces could be easily provided
- Possibility of parallel construction of 2 pipelines
- Possibility of parallel onshore and offshore pipe construction
- Possibility of parallel dredging and pipeline fabrication
- Short duration of marine works
- Short exposure of marine trench

6.2.3 Pulling Vessel

The force required to pull a pipe string with a tow vessel must be sufficient to overcome the resistant factors comprised of the following:

- Longitudinal surface frictional resistance
- Hydrodynamic skin friction along the pipe string; and,
- Hydrodynamic from drag against the towing cable.

The coefficient of longitudinal friction depends upon:

- Pipe characteristics (such as diameter and surface roughness);
- Condition and combination of the pipe.

6.2.4 Anchoring Analysis

For anchorage system, driven piles through the pipeline route as a lateral support mechanism have been selected. Steel pipes are considered to be driven which will be loaded laterally by environmental loads including wind, current and wave forces during the installation phase.

Considering the construction sequences, the dredging depth at pipeline region, shall be added to free board of the piles. Geotechnical parameters for anchorage pile design will be evaluated from current site investigations which are going on in the pipeline region.

6.3 Flooding and Sinking Analysis

Pipe line sinking procedure starts from intake connection points and proceeds toward suction chambers. For submerging of pipeline, the allowable moment and the overall form of pipe curve for gaining such moment are calculated.

Then the system is modeled with ABAQUS software package Ver. 6.10 using shell and beam-column elements and the following main loads applied to:

- Weight of pipe;
- Weight of water in pipe;
- Weight of attachment
- Buoyancy force;
- Reaction of seabed in sitting of pipe on it;
- Environmental loads.

The process of pipe watering will be determined such that the moments are limited to allowable ones.

6.4 Tie-in to Intake

The pipeline will be tied in to the intake basin by connection flange. For this purpose, the seawater will ingress to pipelines at on-shore end and pipelines sinking will be started. During sinking procedure, pipelines will be connected to the intake basin.

7 FITTINGS

Flange and fitting design for onshore tie-in joints to onshore basin and offshore suction chambers shall be according to DIN 16961.and AWWA C207. The rating of flanges and tee shall be selected with due regard to the design pressure and installation forces, bending moment and axial force at flange, operating temperature and flange materials. Rubber gasket shall be used for flanges.

8 BACKFILLING

All of the pipelines should be backfilled by proper materials in such a way that the stability of the pipelines be provided during the service life. As general rules, pipeline will be backfilled up to the sea bed level and the dredged material will be used for the backfilling operation. More details will be explained in “Trenching Depth Calculation & Evaluation Report”.