INTECSEA
WorleyParsons Group

IGI Poseidon

Poseidon Pipeline Project - Offshore Section Update

On-Bottom Stability Design Report

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CONTENTS

1 INTRODUCTION

1.1 Background

The Poseidon Pipeline Project, developed by IGI Poseidon S.A., will be designed for the supply of gas from Turkey and the Eastern Mediterranean region to the European market through the interconnection of the Greek and Italian gas networks.

The Poseidon Pipeline consists of two sections:

- An onshore section, stretching from Kipi (north-east of Greece, next to the Greek Turkish border) to the north western coast of Greece (Thesprotia area);
- An offshore section, from the north-western coast of Greece to Italy (Figure 1-1).

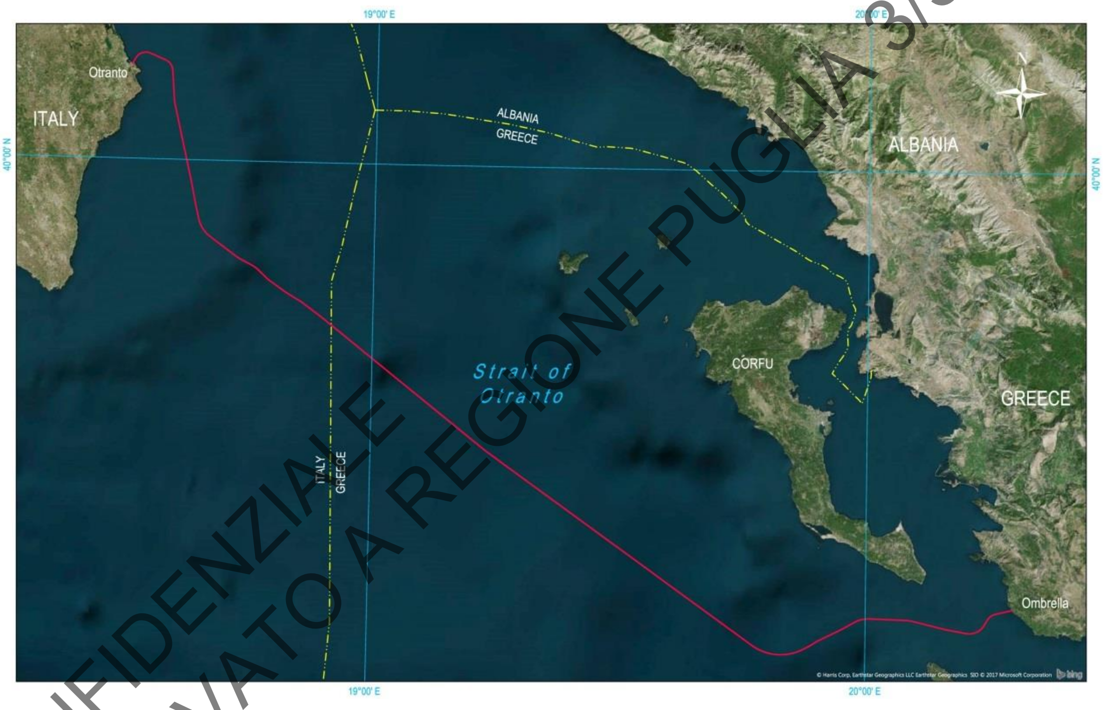

Figure 1-1 Poseidon Pipeline Project – Offshore Section

The offshore section of the Poseidon pipeline comprises:

- A compressor and fiscal metering station next to the Greek landfall (Thesprotia area);
- A deep water offshore pipeline from the Greek landfall to Italy (Otranto, Apulia region). The offshore section (about 200 km, ca. 1,370 m water depth) will cross the Greek shelf, descend the slope into the north Ionian Basin and then ascend the Italian slope, to make landfall east of Otranto;
- A receiving fiscal metering and pressure reduction station in Italy (Otranto, Apulia region);
- Two short buried onshore pipeline sections connecting compressor station in Greece and metering station in Italy to the respective landfalls, including associated scraper launching and receiving facilities.

The FEED phase of the offshore section of the Poseidon Pipeline Project was completed in 2013 and designed for a maximum flow rate of 12 BNCMA of gas (12.66 BSCMA).

ENGINEER's scope of work is named the Poseidon Pipeline Project - Offshore Section Update (the PROJECT). It concerns the Design Update to accommodate a maximum flow rate of 20 BSCMA of gas (which represents a potential development of the gas pipeline, not yet authorized, but evaluated for the maximum design capacity and related technical aspects) for the deep water offshore pipeline from the Greek landfall to Italy (Otranto) and the short onshore buried pipelines connecting compressor station in Greece and fiscal metering and pressure reduction station in Italy to the respective landfalls. Updating of FEED specific aspects for the Greek onshore section, such as the geological, geotechnical, route selection and civil design aspects is not included in the scope.

The document numbers for the FEED Revision have a new CTR number (1000 series).

1.2 Document Scope

The objective of this document is to assess the on-bottom stability for the Italian offshore section of the Poseidon Pipeline Project, using the Methodology as outlined in DNVGL-RP-F109 (Ref. [5]). This results in definition of the minimum required concrete weight coating thickness to ensure hydrodynamic stability.

The assessment is performed for Italian part of the offshore Poseidon route Ombrella-3.2 to Otranto (IGI_OM3.2_OLF_210612). The Italian offshore pipeline section consists of a 32-inch pipeline running from KP 140.0 up to the shore crossing. For details on route definition, reference is made to the Route Selection Report (Ref. [3]).

This document details the on-bottom stability analysis for the exposed section in the operating condition of the Poseidon offshore pipeline.

As detailed in the Shore Crossing Design Report – Italy (Ref. [13]), the Italian shore crossing consists of a HDD section, On-bottom stability analysis is not required for this section.

2 DEFINITIONS AND ABBREVIATIONS

2.1 Definitions

Definitions applicable to the Project are provided in Table 2-1.

Table 2-1 Project Definitions

WORK	Scope of Services per CONTRACT for "Poseidon Pipeline Project – Offshore Section Update"
CONTRACT	The CONTRACT between IGI Poseidon and ENGINEER for WORK as detailed in the CONTRACT documents
CLIENT	IGI Poseidon (50% EDISON S.p.A. and 50% DEPA)
INTECSEA	INTECSEA B.V, the engineering company appointed by CLIENT to carry out the WORK
ENGINEER	INTECSEA
Project	The official title of the Project is "Poseidon Pipeline Project – Offshore Section Update"
INTECSEA Project No.	406010-00159

2.2 Abbreviations

Abbreviations applicable to the Project are provided in Table 2-2.

Table 2-2 Project Abbreviations

3LPP	Three-Layer-Polypropylene
BML	Below Mud-Line
BNCMA	Billion Normal Cubic Meters Per Annum
BSCMA	Billion Standard Cubic Meters Per Annum
CTD	Conductivity, Temperature and Density
CWC	Concrete Weight Coating
DNV	Det Norske Veritas
DMS	Detailed Marine Survey
EOL	End of Life
FEED	Front-End Engineering Design
ID	Inside Diameter
KP	Kilometre Post
NA	Not Applicable
OD	Outside Diameter
OLF	Otranto Landfall
OM3.2	Ombrella 3.2 Landfall
OS	Offshore Standard
RP	Recommended Practice
SG	Specific Gravity
SOL	Start of Life
UTM	Universal Transverse Mercator
WD	Water Depth
WT	Wall Thickness

3 SUMMARY AND CONCLUSIONS

The on-bottom stability analysis has been carried out for the Poseidon offshore pipeline in accordance to the requirements stipulated in DNVGL-RP-F109. The following load cases are considered:

- Installation (empty pipeline; no marine growth)
- Operation - Start of Life (pipeline filled with content; no marine growth)
- Operation - End of Life (pipeline filled with content; marine growth)

Note that on-bottom stability for the hydrotest condition is not assessed as this is not a governing condition due to the significantly higher pipe weight in water-filled condition.

The concrete weight coating (CWC) thicknesses are selected in increments of 10 mm (or a multiple) starting at a minimum thickness of 50 mm up to a maximum thickness of 120 mm. This range is governed by code requirements (minimal thickness) and practical reasons (such as installability and pipe joint handling).

Results for the selected CWC thicknesses are presented in Table 3-1.

Table 3-1 Selected Concrete Coating Thickness

<table>
<tr><th>Section

(km)</th><th>Pipeline Outside Diameter
(mm)</th><th>Pipeline WT

(mm)</th><th>Selected Concrete Coating Thickness
(mm)</th></tr>
<tr><td>KP 140.0 – KP 160.2</td><td rowspan="6">812.8</td><td>30.7</td><td>0</td></tr>
<tr><td>KP 160.2 – KP 162.8</td><td rowspan="4">20.0</td><td>50</td></tr>
<tr><td>KP 162.8 – KP 185.2</td><td>70</td></tr>
<tr><td>KP 185.2 – KP 203.3</td><td>90</td></tr>
<tr><td>KP 203.3 – KP 203.7</td><td>110</td></tr>
<tr><td>KP 203.7 – KP 204.34</td><td>30.7</td><td>120</td></tr>
<tr><td>KP 204.34 – KP 204.81</td><td colspan="3">See Ref. [13]</td></tr>
</table>

4 DESIGN DATA

4.1 General

The following subsections present the relevant data for the on-bottom stability analysis. For all design data, reference is made to the Design Basis Memorandum (Ref. [2]).

4.2 Pipeline Data

4.2.1 Steel Pipeline

Table 4-1 presents the minimum wall thickness requirement along the pipeline as detailed in the Pipeline Mechanical Design Report (Ref. [4]). The 32-inch pipeline has a constant OD of 812.8 mm.

The steel density of 7,850 kg/m^3 is adopted.

Table 4-1 Pipeline Wall Thickness Ref. [4]

Section (km)	Section Length (km)	Pipeline Wall Thickness (mm)
KP 140.0) – KP 160.2	20.2	30.7
KP 160.2 – KP 203.7	43.5	20.0
KP 203.7 – KP 204.8	1.1	30.7

4.2.2 Coating

The pipeline coating data is presented in Table 4-2.

Table 4-2 Pipeline Coating Data

Coating System (-)	Thickness (mm)	Density (kg/m^3)
3 Layer Polypropylene (3LPP)	3.0	960
Concrete	Variable	3,040

Note that the internal flow coating, as its nominal thickness of 0.060 mm is so low, is not considered in the pipeline on-bottom stability analysis.

4.2.3 Content Density

For the Operation load cases, the minimum content density is governing for the on-bottom stability analysis. According to Design Basis Memorandum (Ref. [2]) the minimum content density is 50 kg/m^3.

A content density of 0 kg/m^3 is considered for Installation load cases. (i.e. empty pipe).

4.2.4 Corrosion Allowance

No internal and external corrosion allowances are adopted in the analysis.

4.3 Environmental Data

4.3.1 Seabed Profile

The seabed profile from along the Italian pipeline route section provided in Figure 4-1 is extracted from Design Basis Memorandum Ref. [2].

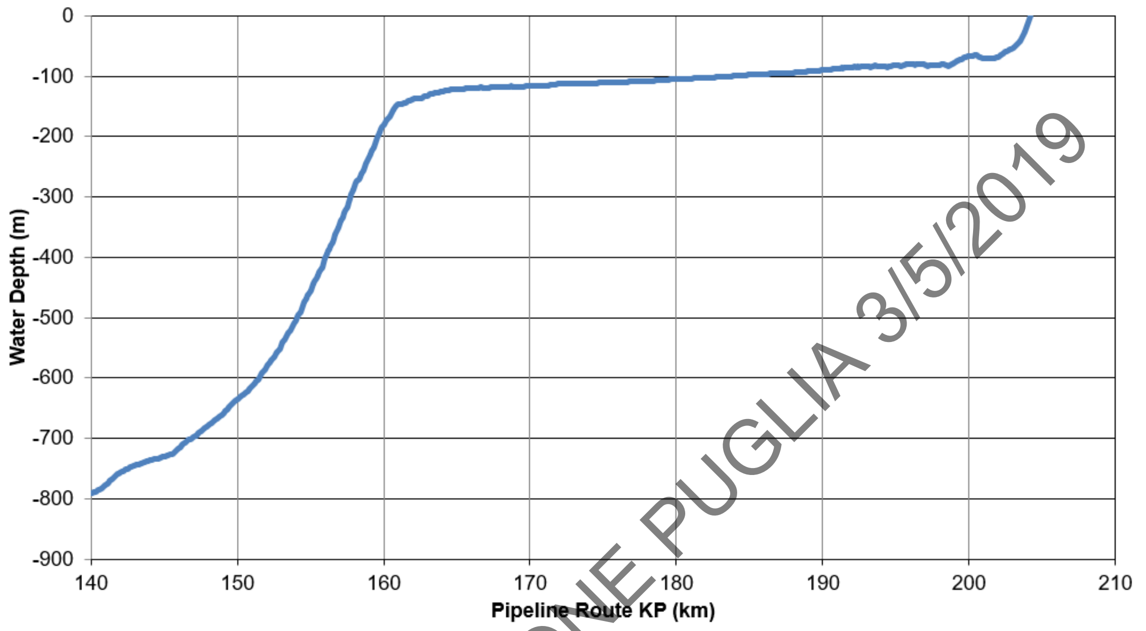

Figure 4-1 Seabed Profile along the Italian Route Section

4.3.2 Seawater Density

As detailed in the Metocean Design Parameters Report Ref. [6] the density of seawater varies from 1025 kg/m³ at the surface to a maximum density of 1035 kg/m³ in deep water.

The seawater density impacts the specific gravity of the pipe, and so its stability. A higher value for seawater density results in a lower pipe specific gravity and thus in a larger concrete weight coating thickness requirement.

Using the CTD (Conductivity, Temperature, and Density) data obtained during the DMS geophysical survey, a typical seawater density profile is provided in Figure 4-2.

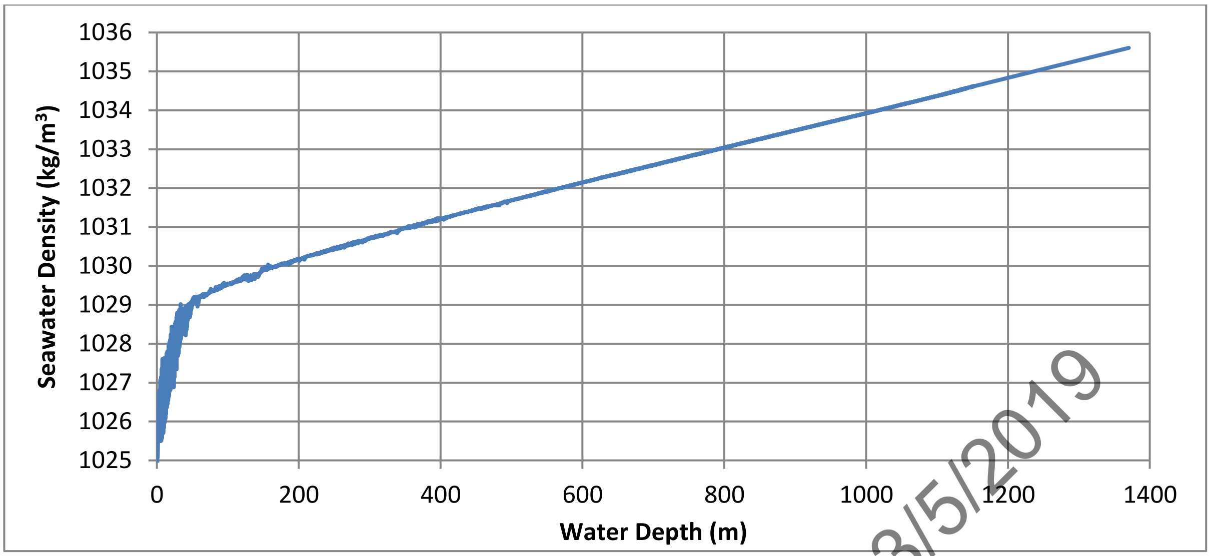

Figure 4-2 Seawater Density Profile

Based on the seawater density profile as shown in Figure 4-2, the following seawater density is applied in the on-bottom stability analysis:

- WD < 90m: 1029.5 kg/m^3
- 90 < WD < 320m: 1031.0 kg/m^3
- WD > 320m: 1035.0 kg/m^3

Where the selected seawater density values represent the maximum value for the selected water depth ranges; see Figure 4-2.

4.3.3 Marine Growth

The marine growth expected for the Poseidon pipeline is given in Table 4-3 according to the Design Basis Memorandum (Ref. [2])

Table 4-3 Marine Growth Data

Water Depth (m)	Thickness (mm)	Density (kg/m^3)
< 200	50	1,280
> 200	0	NA

4.4 Geotechnical Data

The seabed consists mainly of soft clay sediments, with gradually increasing sand/gravel content in the nearshore area, and silt/sand deposits at the landfall.

Soil types along the Poseidon offshore pipeline route have been classified into two groups, as detailed below:

- Type I – Very Soft to Soft CLAY
- Type II – gravelly/silty/clayey SAND, SILT/SAND

Only the relevant soil data for the on-bottom stability design is summarized in Table 4-4. For the detailed information reference is made to the Bathy-Morphological and Geotechnical Route Characterization Study Ref. [7].

Table 4-4 Best Estimate (BE) Soil Parameters along Exposed Pipeline Route

Section	Soil	Submerged Unit Weight	Undrained Shear Strength		Internal Friction Angle
			At 0m BML	At 0.25m BML	
(km)	(-)	(kN/m^3)	(kPa)	(kPa)	(°)
KP 140.0 – KP 161.6	Clay	5.1	3.9	3.9	-
KP 161.6 – KP 195.9	Clay	7.2	5.9	5.9	-
KP 195.9 – KP 204.3	Sand	8.8	-	-	30

4.5 Metocean Data

4.5.1 General

Meteo-Oceanographic data relevant to the design of the Poseidon pipeline are summarized in the Design Basis Memorandum (Ref. [2]). For detailed information, reference is made to the Metocean Design Parameters Report (Ref. [6]).

Table 4-5 and Figure 4-3 show the data points along the offshore pipeline route for which environmental data is obtained in Ref. [6]

Relevant metocean data for the on-bottom stability design is presented in this section.

Figure 4-3 Offshore Route Overview

Table 4-5 Output Location for the Metocean Data

Output Locations	WGS84 - UTM zone 34 N	
	Easting (m)	Northing (m)
12	322554.77	4401033.24
13	312538.02	4408543.4
14	306994.53	4412569.91
15	302281.61	4415993.14
16	296686.19	4429682.23
17	294065.05	4446181.17
18	290828.96	4448557.33
19	288701.84	4448851.64
20	287408.16	4447435.33

Note that output locations are not exactly located along the pipeline route (however < 1 km), due to the pipeline route optimizations.

4.5.2 Wave Data

For the location points as shown in Table 4-5, the directional extreme wave parameters for 1, 10 and 100 year return periods are presented in Appendix B-2 of the Metocean Design Parameters Report (Ref. [6]).

Using the heading along the pipeline route, an assessment has been performed to determine the governing wave direction for each location point shown in Table 4-5. The wave data of the direction causing the largest hydrodynamic pipeline load is presented in Table 4-6.

Note that the wave direction refers to the direction from which the waves are coming. The direction is given in degrees, measured clockwise with respect to the North. Relevant attack angle is determined and applied in the lateral stability calculations.

Table 4-6 Wave Data along Pipeline Route – Ombrella 3.2 to Otranto

Output locations		1-year			10-year			100-year		
Label (-)	KP (km)	H_s (m)	T_p (s)	θ1 (º)	H_s (m)	T_p (s)	θ10 (º)	H_s (m)	T_p (s)	θ100 (º)
12	138.18	5.4	10.4	225	7.0	13.2	225	8.7	16.9	225
13	150.70	5.0	9.9	225	6.6	12.4	225	8.2	15.7	225
14	157.56	6.2	10.9	180	7.6	13.0	180	9.0	15.4	180
15	162.50	5.5	10.0	180	6.7	11.7	180	7.9	13.5	180
16	178.00	4.9	10.4	135	6.2	12.9	135	7.5	15.8	135
17	195.50	4.7	10.4	135	6.2	12.9	135	7.8	15.8	135
18	199.20	4.8	10.0	180	6.2	11.7	180	7.6	13.5	180
19	202.99	4.8	10.0	180	6.2	11.7	180	7.6	13.5	180
20	203.00	4.4	10.4	135	5.6	12.9	135	6.7	15.8	135

4.5.3 Current Data

The maximum near bed current data along the pipeline route for 1, 10 and 100 year return periods are presented in Table 4-7.

Note that the current direction is considered perpendicular to the pipeline along the entire pipeline route due to limited availability of current data.

Table 4-7 Estimated Maximum Nearbed Current Data along Pipeline Route (Ref. [2])

Locations	Output Location	Route KP Range (km)	Current Near Seabed (m/s)		
			1 yr	10 yr	100 yr
Center Strait	12 - 13	138.2 – 160.1	0.3	0.4	0.5
Strait Italy side (50-200m)	14 - 16	160.1 – 203.7	0.6	0.8	1.0
Landfall Italy (<50m)	17 - 19	203.7 -204.14	0.8	1.0	1.2

5 METHODOLOGY

5.1 General

The on-bottom stability analysis is performed using an in-house calculation tool based on the requirements as stipulated in DNVGL-RP-F109 (Ref. [5])

The stability of the submarine pipeline is assessed for the following load conditions:

- Installation (empty pipeline; no marine growth)
- Operation - Start of Life (pipeline filled with content; no marine growth)
- Operation - End of Life (pipeline filled with content; marine growth)

Table 5-1 gives the environmental load combinations for each condition. The combination resulting in the highest hydrodynamic load is governing for the design.

Table 5-1: Load Combinations Ref. [5]

Load Conditions	Dominant Type	Return Periods	
		Current	Wave
Installation (<1 year)	Wave dominant	1-year	10-year
	Current dominant	10-year	1-year
Installation (>1 year); Operation (SOL); Operation (EOL)	Wave dominant	10-year	100-year
	Current dominant	100-year	10-year

From Table 5-1, it can be seen that for temporary phases (i.e. installation) with duration in excess of 12 months, the most severe combination of 10-year and 100-year wave and current data should be applied, according to DNVGL-RP-F109 (Ref. [5]).

As per Project schedule (Ref. [8]) pipeline installation and pre-commissioning (including pipeline flooding) are scheduled in the same season, i.e. within 12 months. As such, for the installation condition, the most severe combination of 1-year and 10-year wave and current data is applied.

Note that shore crossing construction is likely to take place one season in advance given the construction restrictions imposed by the local authorities. As such the nearshore pipeline sections could be empty for a period of 12 to 14 months as per Ref. [5]. However, as the Italian pipeline shore crossing is by HDD, this is considered not to further impact the on-bottom stability analysis.

5.2 DNVGL-RP-F109 Design Requirements

The on-bottom stability analysis of the Poseidon pipeline is determined using the methodology as outlined in DNVGL-RP-F109 (Ref. [5]). This Recommended Practice presents two stability methods:

- Absolute lateral static stability method
- Generalized lateral stability method

The absolute static stability method allows no lateral movement of the pipeline under the design extreme single wave cycle, while the generalized method allows lateral movement up to 10 times the pipe diameter under the design significant wave induced particle velocity. Both lateral stability methods are further described in the subsequent sections.

The aim of the stability analysis is to verify that the submerged weight of the pipeline complies with the stability criteria stipulated in the design code DNVGL-RP-F109 (Ref. [5]) which consists of:

- Vertical stability in water (flotation)
- Verification of no-sinking (buried or unburied) in soil
- Verification of lateral stability subjected under environmental loads

5.2.1 Vertical Stability in Water

The pipeline shall have the submerged weight such that it will meet the following requirement:

$$\gamma_w \cdot \frac{B}{W_s + B} = \frac{\gamma_w}{s_g} \leq 1.00$$

Where,

W_s	=	Submerged weight per unit length
B	=	Buoyancy per unit length, N/m
γ_w	=	Safety Factor

As per Ref. [5] the safety factor can be taken equal to 1.1 if a sufficiently low probability of negative buoyancy is not documented. This safety factor covers for potential weight differences between pipe joints; applying a value of 1.1 provides a 10% margin to ensure that even the lightest pipe joint is still negatively buoyant.

5.2.2 Vertical Stability on Seabed and in Soil

Vertical stability on and in soil is to be verified based on the design procedure stipulated in DNVGL-RP-F109 Section 3.3 (Ref. [5]) by adopting the expressions for the static vertical soil reaction per unit length as a function of the vertical penetration z given in DNVGL-RP-F114 (Ref. [11]). These expressions for sand and clay are based on the following bearing capacity formulas for ideal 2-D strip foundations.

Sand (drained condition)

$$Q_v = 0.5 \cdot \gamma' \cdot N_\gamma \cdot B^2 \cdot + z_0 \cdot \gamma' \cdot N_\gamma \cdot d_q \cdot B$$

Clay (undrained condition)

$$Q_v = Q_{v0} \cdot (1 + d_{ca}) + \gamma_s A_{bm}$$

In which

$$B = \begin{cases} 2\sqrt{(D-z)z} & for\, v \le 0.5D \\ D & for\, v > 0.5D \end{cases}$$

Where

Q_v = Vertical force required to penetrate the pipe to the embedment z

Q_{v0} = Bearing capacity (not including depth effects or soil buoyancy z

$$Q_{v0} = F \cdot (N_c \cdot s_{u,0} + \rho \cdot B / 4) \cdot B$$

γ' = Minimum submerged specific weight of soil

B = Contact width for pipe-soil load transfer

d_{ca} = Depth correction factor

D = Outer pipe diameter including coatings

z = Vertical penetration, m

z_0 = Reference z-level for depth effects

A_{bm} = Cross-sectional area of penetrated part of pipe,

C_u = Undrained shear strength

N_c = Bearing capacity factor for clay. For pipes considered as smooth, the bearing capacity factor may be taken as 5.14 for small penetrations, but could reduce to 4 when the pipe embedment is equal to z=D/2 due to the circular arc shaped foundation base.

According to DNVGL-RP-F114 the dimensionless bearing capacity factors N_q, and N_γ (range) depend on the angle of internal friction φ_s and may be calculated from the following formulas:

$$N_q = \exp(\pi \tan\varphi_s)\tan^2\left(45^o + 0.5\varphi_s\right)$$

$$N_\gamma = 2\left(N_q + 1\right)\tan\varphi_s$$

$$N_\gamma = 1.5\left(N_q - 1\right)\tan\varphi_s$$

in which $\varphi_s = 0^o$ for clayey soils.

The verification against sinking implies that the maximum submerged weight of the pipe shall satisfy the following requirement if the maximum submerged specific weight of the pipeline (flooded) exceeds the specific weight of the soil:

$$W_s < Q_{v;0.5D}$$

If

$$\gamma_{\max} > \gamma_s$$

Where,

W_s = Submerged weight per unit length of the pipe

$Q_{v;0.5D}$ = Static vertical soil reaction per unit length for a vertical penetration *z=0.5D*

$\gamma_{\max}$ = Submerged specific weight of the seawater-filled pipe

5.2.3 Lateral Stability

5.2.3.1 Generalized Lateral Stability Method

Stability is verified by the following equation given in Section 2.5 of DNVGL-RP-F109:

$$\frac{Y(L, K, M, N, \tau, G_s)}{Y_{al.}} \leq 1.00$$

Where,

Y = Dimensionless lateral pipe displacement

$Y_{al.}$ = Allowed lateral displacement scaled to pipe diameter; for both temporary and operating conditions limited to 10 pipe diameters

L = Significant weight parameter

K = Significant Keulegan-Carpenter number

M = Steady to oscillatory velocity ratio for design spectrum

N = Spectral acceleration factor

τ = Number of oscillations in the design bottom velocity spectrum

G_s = Soil (sand) density parameter

Since there are a relatively limited number of input parameters, the on-bottom stability problem is well suited for establishing databases in which the pipe displacement is given for its set of input parameters. The design code DNVGL-RP-F109 (Ref. [5]) provides design curves for on-bottom stability design with an allowed lateral displacement in the range from less than half a pipe diameter, i.e. for a virtually stable pipe, up to a significant displacement of 10 diameters during the given sea state. These curves are obtained from a large number of one-dimensional dynamic analyses.

5.2.3.2 Absolute Lateral Static Stability Method

The absolute lateral static stability method provides an absolute static requirement for pipelines based on static equilibrium of lateral forces. Application of this method ensures that the resistance of the pipe against motion is sufficient to withstand maximum hydrodynamic loads during a sea state, i.e. the pipe will experience no lateral displacement under the design extreme single wave induced oscillatory cycle in the sea state considered.

A pipeline can be considered to satisfy the absolute static stability requirement if:

$$\gamma_{SC} \cdot \frac{F_Y^* + \mu \cdot F_Z^*}{\mu \cdot W_s + F_R} \leq 1.00$$

and

$$\gamma_{SC} \cdot \frac{F_z^*}{W_s} \leq 1.00$$

Where,

γ_{SC} = Safety Factor

F_Y^* = Maximum horizontal hydrodynamic load during sea state, N/m

F_Z^* = Maximum vertical hydrodynamic load during sea state, N/m

F_R = Passive soil resistance, N/m

μ = Coefficient of friction

W_s = Submerged weight per unit length, N/m

5.2.3.3 Evaluation

For the exposed sections of the Italian part of the Poseidon pipeline (from KP 140.0 to the HDD exit pit) the minimum required concrete weight coating is calculated for both methods, i.e. generalized lateral stability method and absolute lateral static stability method.

Typically, the absolute stability method requires the heaviest pipe, whereas the generalized stability method (10xOD) requires the lightest pipe.

Especially for cases dominated by wave induced flow velocity with small amplitude, i.e. *K* and *M* are small; the absolute stability method normally leads to a heavy pipe. Note also that with a zero displacement requirement, one cannot take advantage of the increased passive resistance that is built up due to the penetration caused by the pipe being rugged back and forth by the wave induced flow.

However, as pointed out in DNVGL-RP-F109 (Ref. [5]) the generalized lateral stability method could result in large weight requirements for certain combinations of wave, current and soil data:

- Deep water (current dominated flow);
- Seabed consisting of stiff clay.

For the Poseidon pipeline, it is concluded that for the shallow water section of the pipeline (i.e. the pipe sections requiring concrete weight coating), the generalized stability method (10xD) results in the lowest (or equal) concrete weight coating requirement compared to the absolute stability method. As such, this criterion is adopted for the Project.

5.2.4 Soil Liquefaction

Soil liquefaction denotes the phenomenon that the soil loses a significant part of – or all – its shear strength. Liquefaction may occur due to cyclic shear stresses, imposed by waves or earth quakes, that generate excessive pore pressure until the soil loses a significant part of its shear strength (residual liquefaction) or if a steep wave travels over a loose soil inducing an upward-directed pressure gradient under the wave through (instantaneous liquefaction).

Depending on the specific gravity of the pipe, soil liquefaction may make a heavy pipe laid on the seabed to sink into the soil and (partly) bury itself, or make a light (and buried) pipe to float up through the soil.

Soil liquefaction assessment along the offshore pipeline is further detailed as part of the Slope Stability and Liquefaction Assessment Report (Ref. [16]).

5.3 Pipeline Route Segmentation (Load Cases)

The concrete coating thickness along the offshore route varies given the variation in water depth, soil characteristics and metocean data. For each location along the pipeline route the minimum required concrete coating thickness is analysed in accordance with DNVGL-RP-F109 (Ref. [5])

For reporting purposes, the Italian part of the Poseidon offshore pipeline is divided in segments as shown in Table 5-2. The selected transitions represent changes in pipeline wall thickness, metocean conditions (wave, current data), soil conditions, or pipeline heading / orientation.

Note that the on-bottom analysis as presented in this document does not consider the shore approach section. The results presented in this document are limited to the exposed section, from KP 140.0 upto the HDD exit pit.

Since the pipeline shore crossing is by means of HDD (Ref. [13]) on-bottom stability analysis are not required.

Table 5-2 Pipeline Segmentation

Section		**Wall Thickness**	**Soil Type**	**Wave Data**	**Near Seabed Current Velocity 1 yr**	**Pipeline Heading[1]**	**Minimum Water Depth**
Start (km)	**End** (km)	(mm)	(-)	(-)	(m/s)	(°)	(m)
140.0	160.2	30.7		12# – 14#	0.3	307	200
160.2	161.6			14# - 15#			144
161.6	162.8					307	135
162.8	166.8		Clay	15# - 16#			118
166.8	178.3					350	108
178.3	185.2						98
185.2	195.9	20.0		16# - 17#	0.6	357	82
195.9	199.5		Sand	17# - 18#		294	80
199.5	201.9			18# - 19#			70
201.9	203.3		Sand			210	57
203.3	203.7			20#			50
203.7	204.34	20.0 / 30.7	Sand	20#	0.8	210	40
204.34	204.81	See Ref. [13]					

Note 1: The pipeline heading refers to the North (clockwise).

6 RESULTS

6.1 Minimum Required Concrete Coating Thickness

6.1.1 Vertical Stability

The minimum required concrete weight coating thickness to achieve pipeline vertical stability as per Section 5.2.3.1 for the applied line pipe wall thicknesses is presented in Table 6-1.

Table 6-1 Minimum Required Concrete Coating Thickness for Vertical Stability

Pipeline Wall Thickness (mm)	Pipeline Outside diameter (mm)	Minimum Required Concrete Coating Thickness (mm)
30.7	812.8	0
20.0		39

6.1.2 Lateral Stability

The minimum concrete coating thickness required to achieve pipeline lateral stability as per Section 5.2.3 for the Poseidon offshore pipeline is presented in Table 6-2.

Table 6-2 Minimum Required Concrete Coating Thickness

Section (km)	Pipeline Outside Diameter (mm)	Pipeline Wall Thickness (mm)	Minimum Required Concrete Coating Thickness (mm)
KP 140.0 – KP 160.2	812.8	30.7	0
KP 160.2 – KP 161.6		20.0	43
KP 161.6 – KP 162.8			46
KP 162.8 – KP 166.8			52
KP 166.8 – KP 178.3			59
KP 178.3 – KP 185.2			68
KP 185.2 – KP 195.8			82
KP 195.8 – KP 199.5			55
KP 199.5 – KP 201.9			62
KP 201.9 – KP 203.3			64
KP 203.3 – KP 203.7			103
KP 203.7 – KP 204.34		20.0 / 30.7	134 / 97
KP 204.34 – KP 204.81	See Ref. [13]		

Note that the minimum required concrete weight coating thickness exceeds 120 mm at the nearshore section (from KP 203.7 to KP 204.34) for the 20.0 mm pipeline wall thickness. This will is further discussed in the Section 6.2.

6.2 Discussion of Concrete Coating Selection in Shore Approach

In the Italian nearshore area, from KP 203.7 to 204.34, the on-bottom stability analysis demonstrates that a concrete weight coating thickness of over 120 mm is required. To reduce the required concrete weight coating thickness in this section, several available solutions, or combinations of solutions, are available:

- Increase wall thickness from 20.0 mm to 30.7 mm, i.e. extend length of wall thickness value applied in shore approach area (higher DNV safety class), with this solution a concrete weight coating of 97 mm is required.
- Use more accurate metocean data, if available. In Ref. [6] the recommendation has been made to commission field measurements with current meters at selected locations along the pipeline route.
- Bury pipeline section:
    - Extent transition trench at HDD exit point and provide active backfill

    - Perform rock dumping or post-trenching as part of seabed intervention campaign

Given the effectiveness of the solution to extend the length of wall thickness of 30.7 mm value applied in shore approach area, this solution is adopted from KP 203.7 up to KP 204.34 to satisfy the on-bottom stability criteria.

To improve stability at HDD section exit, a 120mm CWC thickness is selected.

6.3 Selected Concrete Coating Thickness

The concrete weight coating thicknesses are selected in increments of (a multiple of) 10 mm starting at a minimum thickness of 50 mm up to a maximum of 120 mm

As detailed in Section 5, the concrete coating thickness design as per DNVGL-RP-F109 contains the following design conditions:

- Vertical stability in water, on seabed, and in soil
- Lateral stability (following the absolute method and generalized method)

The selected concrete coating thicknesses along the offshore section of the Poseidon pipeline is presented in Table 6-3.

Table 6-3 Selected Concrete Coating Thickness

<table>
<tr><th>Section</th><th>Pipeline OD
(mm)</th><th>Pipeline WT
(mm)</th><th>Selected Concrete Coating Thickness
(mm)</th><th>Water Depth Range
(m)</th></tr>
<tr><td>KP 140.0 – KP 160.2</td><td>910.8</td><td>34.4</td><td>0</td><td>800 - 200</td></tr>
<tr><td>KP 160.2 – KP 161.6</td><td rowspan="11">812.8</td><td rowspan="10">20.0</td><td>50</td><td>200 - 144</td></tr>
<tr><td>KP 161.6 – KP 162.8</td><td>50</td><td>144 - 135</td></tr>
<tr><td>KP 162.8 – KP 166.8</td><td>70</td><td>135 - 118</td></tr>
<tr><td>KP 166.8 – KP 178.3</td><td>70</td><td>118 - 108</td></tr>
<tr><td>KP 178.3 – KP 185.2</td><td>70</td><td>108 - 98</td></tr>
<tr><td>KP 185.2 – KP 195.8</td><td>90</td><td>98 - 82</td></tr>
<tr><td>KP 195.8 – KP 199.5</td><td>90</td><td>82 - 80</td></tr>
<tr><td>KP 199.5 – KP 201.9</td><td>90</td><td>80 – 70</td></tr>
<tr><td>KP 201.9 – KP 203.3</td><td>90</td><td>70 - 57</td></tr>
<tr><td>KP 203.3 – KP 203.7</td><td>110</td><td>57 - 48</td></tr>
<tr><td>KP 203.7 – KP 204.34</td><td>30.7</td><td>120</td><td>48 - 40</td></tr>
<tr><td>KP 204.34 – KP 204.81</td><td colspan="4">See Ref. [13]</td></tr>
</table>

Note1: Just before the HDD exit the CWC thickness has been increased to 120 mm where the minimum required concrete thickness is 97 mm.

7 REFERENCES

Ref. [1] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Document Control System & Communication Protocol, Doc. No. IGI-102-00-PM-PRO-001

Ref. [2] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Design Basis Memorandum, Doc. No. IGI-1201-10-PL-BOD-001

Ref. [3] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Route Selection Report, Doc. No. IGI-302-30-PL-RPT-001

Ref. [4] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Pipeline Mechanical Design Report, Doc. No IGI-1308-30-PL-RPT-001

Ref. [5] Det Norske Veritas, On-Bottom Stability Design of Submarine Pipelines, Doc. No DNVGL-RP-F109

Ref. [6] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Metocean Design Parameters Report, Doc. No. IGI-303-30-RPT-001

Ref. [7] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Bathy-Morphological and Geotechnical Route Characterisation, Doc. No. IGI-302-30-PL-RPT-002

Ref. [8] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Project Schedule Level II and III, Doc. No. IGI-219-10-PL-SCH-001

Ref. [9] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Pre-Commissioning Philosophy, Doc. No. IGI-206-10-PL-PHL-001

Ref. [10] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Specification for Line Pipe, Doc. No. IGI-1207-PL-SPC-001

Ref. [11] Det Norske Veritas, Soil Interaction for Submarine Pipelines, Doc. No. DNVGL-RP-F114

Ref. [12] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Slope Stability and Liquefaction Assessment, Doc. No. IGI-305-30-HS-RPT-004

Ref. [13] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Shore Crossing Design Report - Italy, Doc. No. IGI-1314-30-RPT-003

Ref. [14] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Pipeline Alignment Sheets, DWG. No. IGI-1316-PL-DWG-001

Ref. [15] Fugro Geoconsulting Limited, WE9 Survey Data Report, Book B: Geohazard Core Logging Report, J35002-SDR9-B(1)

Ref. [16] INTECSEA Poseidon Pipeline Project – Offshore Section Update, Slope Stability and Liquefaction Assessment Report, Doc. No. IGI-305-30-HS-RPT-004