MANUAL FOR DESIGN AND LAYING OF SUBMARINE PIPELINES USING HIGH DENSITY POLYETHYLENE (HDPE) PIPES

INHOUSE MANUAL

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INDOMER COASTAL HYDRAULICS (P) LTD.

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ABBREVIATIONS

OD	-	Outer diameter
ID	-	Inner diameter
ND	-	Nominal diameter
MLD	-	Million litters per day
SDR	-	Standard dimensions ratio
HDPE	-	High density polyethylene
MDPE	-	Medium density polyethylene
MPa	-	Megapascal
MRS	-	Minimum required strength
PE	-	Material Grade
IS	-	Indian standard
ES	-	European standard
m	-	Meter
mm	-	Millimetre

1. INTRODUCTION

1.1. HDPE Pipes

HDPE pipe is a type of flexible plastic pipe used for fluid and gas transfer and is often used to replace ageing concrete or steel mains pipelines. Made from the thermoplastic HDPE (high-density polyethylene), its high level of impermeability and strong molecular bond make it suitable for high pressure pipelines. HDPE pipe is used across the globe for applications such as water mains, gas mains, sewer mains, slurry transfer lines, rural irrigation, fire system supply lines, electrical and communications conduit, and stormwater and drainage pipes.

HDPE pipes are best preferred for potable water supply, irrigation schemes, chemicals and edibles transportation, effluent / slurry collection and disposal system, submarine and underwater pipelines, hydro transport system, gas/compressed air system, cable ducting etc.

HDPE pipes have been preferred over other available resources due to varied salient features described below.

- High corrosion resistance, resulting into a longer life.
- High impact strength.
- Extremely light weight and hence easy to handle.
- High flexibility.
- High abrasion resistance.
- Excellent water hammer characteristics, helps sustaining surges.
- Excellent flow characteristics leading to significant energy saving.
- No exfiltration and infiltration, helps maintaining the quality of fluid being conveyed.
- High UV resistance.
- High resistance to scaling and biological build up.
- High chemical resistance, absolutely inert to any pH value.
- Virtually maintenance free.

1.2. Applications of HDPE Pipes

Industrial	Agricultural
Submarine pipelines in seawater intake and outfall in desalination plants	Water supply for irrigation in fields
In petrochemical, paper, dye, paint, cement and other chemical industries for disposal of chemical effluent and waste.	Drip irrigation scheme
Oil and milk transportation in industries and dairies	Sprinkler irrigation
Acid and Slurries transportation	Insecticide spraying
Compressed gas supply at mines and construction sites	Drawing water from pump set for distribution
External & internal drainage and sewage	Most suitable for submersible pumps and jet pumps.
Saltwater handling	-

Pipes made from Polyethylene (PE) is a cost effective answer for a number of piping problems in Metropolitan, Municipal, Industrial, Underwater, Mining, Landfill Gas extraction, Cable duct and agricultural applications. It has been tested and proven effective for underground, above ground, surface, under water as well as floating pipe applications.

Polyethylene pipes both High Density (HDPE) and Medium Density (MDPE) can carry potable water, wastewater, slurries, chemicals, hazardous wastes, cables and compressed gases as well as oils. Polyethylene pipes have a long and successful service experience to the gas oil, mining and water utility industries. PE pipes have the lowest repair frequency per Kilometer of pipe per year compared with all other pipe materials used for urban water and gas distribution.

Selection of Pipelines

- Diameter of pipe
- Standard Dimension Ratio (SDR) is the pressure rating for piping. SDR is the ratio of the outer pipe diameter (D) to wall thickness (s)
- PE80 or PE100 relates to the strength of the pipe in accordance with ISO 12162.
- Length of pipe
- Bed rocks / seabed nature
- Hydrodynamic nature of seabed

1.3. Standard Pipe Diameter

Based on IS: 4984, Year 2016, HDPE pipes vary from 160 mm to 2500 mm. The availability of HDPE pipe size (diameter) with appropriate wall thickness as per Bureau of Indian Standards is given below.

This Indian Standard lays down requirements for high density polyethylene pipes from 16 mm to 1000 mm nominal diameter of pressure ranging from 0.25 MPa to 1.6 MPa in material grades of PE 63, PE 80 and PE 100 for use for buried water mains and services. The pipes shall be classified according to the grade of material as described below.

Table 1.1. Classification of Pipe Material

Material Grade	MRS (Minimum Required Strength) of Material in MPa at 20°C	Maximum Allowable Hydrostatic Design Stress (σ), MPa	
		At 20°C	At 30°C
PE 63	6.3	5.0	4.0
PE 80	8.0	6.3	5.0
PE 100	10.0	8.0	6.3

Source: IS 4984: 1995

Based on the above grade of material, the minimum and maximum wall thickness of HDPE pipes for the three grades of materials viz., Pe 63, PE 80 and PE 100 is given below in Table 1.2, 1.3 and 1.4 respectively.

Table 1.2. Wall Thickness of pipes for Material Grade PE 63

(All dimensions are in mm)

Nominal Diameter	PN 2.5		PN 4		PN 6		PN 10		PN 12.5		PN 16	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
16	-	-	-	-	-	-	-	-	2.2	2.6	2.7	3.2
20	-	-	-	-	-	-	2.3	2.8	2.7	3.2	3.4	3.9
25	-	-	-	-	2	2.4	2.8	3.3	3.4	4	4.2	4.8
32	-	-	-	-	2.3	2.7	3.6	4.2	4.4	5	5.4	6.1
40	-	-	2	2.4	2.8	3.3	4.5	5.1	5.5	6.2	6.7	7.6
50	-	-	2.4	2.9	3.5	4.1	5.6	6.4	6.8	7.7	8.4	9.4
63	2	2.4	3	3.5	4.4	5.1	7	7.9	8.6	9.6	10.5	11.8
75	2.3	2.7	3.6	4.2	5.3	6	8.4	9.4	10.2	11.4	12.5	14
90	2.8	3.2	4.3	5	6.3	7.2	10	11.2	12.2	13.6	15	16.7
110	3.4	3.9	5.3	6	7.7	8.7	12.3	13.7	14.9	16.6	18.4	20.4
125	3.8	4.4	6	6.8	8.8	9.8	13.9	15.5	16.9	18.8	20.9	23.2
140	4.3	4.9	6.7	7.6	9.8	11	15.6	17.4	19	21.1	23.4	25.9
160	4.9	5.6	7.7	3.6	11.2	12.5	17.8	19.8	21.7	24	26.7	29.6
180	5.5	6.2	8.6	9.7	12.6	14.1	20	22.2	24.4	27	30	33.2
200	6.1	6.9	9.6	10.7	14	15.6	22.3	24.7	27.1	30	33.4	36.9
225	6.9	7.7	10.8	12	15.7	17.5	25	27.9	30.5	33.7	37.5	41.5
250	7.6	8.6	11.9	13.3	17.5	19.4	27.8	30.8	33.8	37.4	41.7	46.1
280	8.5	9.6	13.4	14.9	19.6	21.7	31.2	34.5	37.9	41.9	46.7	51.6
315	9.6	10.7	15	16.7	22	24.4	35	38.7	42.6	47.1	52.5	58
355	10.8	12.1	16.9	18.8	24.8	27.5	39.5	43.6	48	53	59.2	65.3
400	12.2	14.2	19.1	22.1	28	32.3	44.5	51.4	54.1	62.4	-	-
450	13.7	15.9	21.5	25	31.4	36.3	50	57.7	-	-	-	-
500	15.2	17.7	23.9	27.6	34.5	40.4	55.6	64.1	-	-	-	-
560	17	19.8	26.7	30.9	39.1	45.2	-	-	-	-	-	-
630	19.1	22.2	30	34.7	44	50.8	-	-	-	-	-	-
710	21.6	25	33	39.1	49.6	57.2	-	-	-	-	-	-
800	24.3	28.1	38.1	44.1	55.9	64.4	-	-	-	-	-	-
900	27.3	31.6	42.9	49.5	-	-	-	-	-	-	-	-
1000	30.3	35.1	47.7	55	-	-	-	-	-	-	-	-

Source: IS 4984: 1995

Table 1.3. Wall Thickness of pipes for Material Grade PE 80

(All dimensions are in mm)

Nominal Diameter	PN 6		PN 10		PN 12.5		PN 16	
	Min	Max	Min	Max	Min	Max	Min	Max
16	-	-	-	-	-	-	2.3	2.7
20	-	-	1.9	2.3	2.3	2.7	2.8	3.3
25	-	-	2.3	2.7	2.8	3.3	3.5	4
32	1.9	2.3	3	3.4	3.6	4.2	4.5	5.1
40	2.3	2.7	3.7	4.3	4.5	5.1	5.6	6.3
50	2.9	3.4	4.6	5.3	5.6	6.4	6.9	7.8
63	3.6	4.2	5.8	6.6	7	7.9	8.7	9.8
75	4.3	4.9	6.9	7.8	8.4	9.4	10.4	11.6
90	5.1	5.8	8.2	9.3	10	11.2	12.5	13.9
110	6.3	7.1	10	11.2	12.3	13.8	15.2	16.9
125	7.1	8	11.4	12.8	13.9	15.5	17.3	19.2
140	8	9	12.8	14.3	15.6	17.4	19.4	21.5
160	9.1	10.2	14.6	16.3	17.8	19.8	22.1	24.5
180	10.2	11.5	16.4	18.3	20	22.2	24.9	27.6
200	11.4	12.7	18.2	20.3	22.3	24.7	27.6	30.6
225	12.8	14.3	20.5	22.8	25	27.7	31.1	34.4
250	14.2	15.8	22.8	25.3	27.8	30.8	34.5	38.2
280	15.9	17.7	25.5	28.3	31.2	34.5	38.7	42.7
315	17.9	20	28.7	31.8	35	38.7	43.5	48
355	20.1	22.3	32.3	35.8	39.5	43.6	49	54.1
400	22.7	26.3	36.4	42.1	44.5	51.4	55.2	63.7
450	25.5	29.5	41	47.4	50	57.7	-	-
500	28.3	32.8	45.5	52.5	55.6	64.1	-	-
560	31.7	36.7	51	58.8	-	-	-	-
630	35.7	41.3	57.3	66.1	-	-	-	-
710	40.2	46.5	-	-	-	-	-	-
800	45.3	52.3	-	-	-	-	-	-
900	50.1	58.8	-	-	-	-	-	-
1000	56.6	65.3	-	-	-	-	-	-

Source: IS 4984: 1995

Table 1.4. Wall Thickness of pipes for Material Grade PE 100

(All dimensions are in mm)

Nominal Diameter	Wall thickness of pipes for pressure Ratings of					
	PN 10		PN 12.5		PN 16	
	Min	Max	Min	Max	Min	Max
16	-	-	-	-	1.9	2.3
20	-	-	1.9	2.3	2.3	2.7
25	1.9	2.3	2.3	2.7	2.9	3.3
32	2.4	2.8	2.9	3.4	3.7	4.2
40	3	3.5	3.7	4.2	4.6	5.2
50	3.7	4.3	4.6	5.2	5.7	6.4
63	4.7	5.3	5.8	6.5	7.1	8.1
75	5.6	6.3	6.8	7.7	8.5	9.5
90	6.7	7.5	8.2	9.2	10.2	11.4
110	8.1	9.1	10	11.2	12.4	13.9
125	9.2	10.4	11.3	12.7	14.1	15.7
140	10.3	11.6	12.7	14.1	15.8	17.6
160	11.8	13.2	14.5	16.1	18.1	20.1
180	13.3	14.8	16.3	18.1	20.3	22.6
200	14.8	16.4	18.1	20.1	22.6	25
225	16.6	18.4	20.4	22.6	25.4	28.1
250	18.4	20.5	22.6	25.1	28.2	31.2
280	20.6	22.9	25.3	28	31.6	35
315	23.2	25.7	28.5	31.5	35.5	39.3
355	26.1	29	32.1	35.5	40	44.2
400	29.5	34.1	36.1	41.8	45.1	52.1
450	33.1	38.8	40.7	47	50.7	58.6
500	36.8	42.5	45.2	52.1	56.4	65
560	41.2	47.6	50.6	58.4	-	-
630	46.8	53.5	56.9	65.6	-	-
710	52.3	60.3	-	-	-	-
800	58.9	67.9	-	-	-	-
900	-	-	-	-	-	-
1000	-	-	-	-	-	-

Source: IS 4984: 1995

1.4. Standards for Large Diameter Pipe

Based on IS: 4984, Year 2016, HDPE pipes vary from 160 mm to 2500 mm. The availability of HDPE pipe size (diameter) with appropriate wall thickness as per Bureau of Indian Standards is given in Table 1.5 and Table 1.6

Table 1.5. Standards for large diameter pipeline - IS

Wall thickness chart for HDPE pipe as per IS: 4984, YEAR 2016

(The wall thickness are calculated on maximum allowable operating pressure at 27°c) All dimensions are in mm

SDR	SDR 41		SDR 33		SDR 26		SDR 21		SDR 17		SDR 13.6		SDR 11		SDR 9	
Nominal pressure, PN in bar																
PE 63	PN 2		PN 2.5		PN 3.2		PN 4		PN 5		PN 6		PN 8		-	
PE80	PN 2.5		PN 3.2		PN 4		PN 5		PN 6		PN 8		PN 10		PN 12.5	
PE 100	PN 3		PN 4		PN 5		PN 6		PN 8		PN 10		PN 12.5		PN 16	
(OD)	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1000	24.4	26.9	30.3	33.4	38.5	42.5	47.7	52.6	58.9	64.9	73.6	81.1	90.9	100.1	111.2	122.4
1200	29.3	32.3	36.4	40.1	46.2	50.9	57.2	63	70.6	77.8	88.3	97.2	109.1	120.1	-	-
1400	34.1	37.6	42.5	46.9	53.9	59.4	66.7	73.5	82.4	90.7	103	113.4	-	-	-	-
1600	39	43	48.5	53.5	61.6	67.9	76.2	83.9	94.2	103.7	117.7	129.6	-	-	-	-
1800	43.9	48.4	54.6	60.2	69.3	76.3	85.8	94.5	105.9	116.6	-	-	-	-	-	-
2000	48.8	53.8	60.6	66.8	77	84.8	95.3	104.9	117.7	129.6	-	-	-	-	-	-

Source: *http://www.jains.com/Pipefittings/hdpe%20pipe.htm*

continued...

Table 1.6. Standards for large diameter pipeline - EN

Wall thickness chart for HDPE pipe as per BS EN 12201-2, year 2011

(The wall thickness are calculated on maximum allowable operating pressure at 27°c) All dimensions are in mm

SDR		SDR 41		SDR 33		SDR 26		SDR 21		SDR 17		SDR 13.6		SDR 11		SDR 9	
Nominal pressure, PN in bar																	
PE 80		PN 3.2		PN 4		PN 5		PN 6		PN 8		PN 10		PN 12.5		PN 16	
PE 100		PN 4		PN 5		PN 6		PN 8		PN 10		PN 12.5		PN 16		PN 20	
Nominal Dia.		W.T		W.T		W.T		W.T		W.T		W.T		W.T		W.T	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1000	1009	24.5	27.1	30.6	33.5	28.2	42.2	47.7	52.6	59.3	65.4	73.5	80.9	90.8	100	-	-
1200	1210.8	29.4	32.5	36.7	40.5	45.9	50.6	57.2	63.1	71.1	78.4	88.2	97.2	-	-	-	-
1400	1412.6	34.3	37.9	42.9	47.3	53.5	59	66.7	73.5	83	91.5	102.8	113.3	-	-	-	-
1600	1614.4	39.2	43.3	49	54	61.2	67.5	76.2	84	94.8	104.4	117.5	129.4	-	-	-	-
1800	1816.2	44	48.6	55.1	60.8	68.8	75.8	85.8	94.5	106.6	117.4	-	-	-	-	-	-
2000	2018	48.9	53.9	61.2	67.5	76.4	84.2	95.3	105	118.5	130.4	-	-	-	-	-	-
2250	2270.3	55	60.7	68.9	75.9	86	94.8	107.2	118.1	-	-	-	-	-	-	-	-
2500	2522.5	61.2	67.5	76.5	84.3	95.8	105.2	119.1	131.2	-	-	-	-	-	-	-	-

Source: *http://www.jains.com/Pipefittings/hdpe%20pipe.htm*

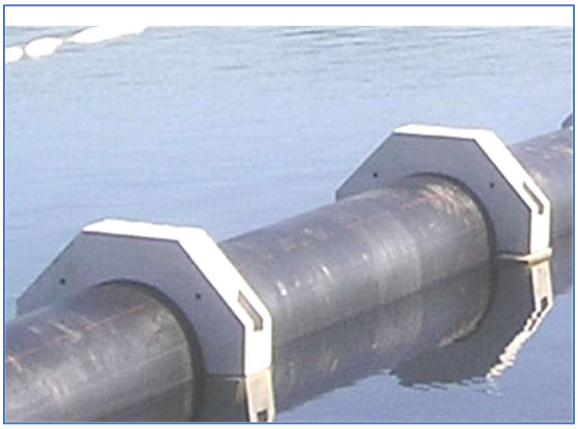
2. CONCRETE ANCHOR BLOCKS

HDPE pipelines are normally used in any seawater intake and outfall system preferred in a desalination plant. In desalination plant application, the HDPE pipelines will be buried below the seabed with and intake head and outfall diffuser at its offshore end. Generally, the length of pipelines will be restricted within the nearshore region for withdrawal of seawater and discharge of brine reject for desalination plant. In this environment, the pipeline is influenced by external forces due to waves and current in the sea. In order to keep the pipeline intact with its aligned corridor, concrete blocks is used to anchor the pipelines intact with the seabed.

2.1. Anchor Blocks

A conventional anchor block is a reinforced concrete block which is cast around a straight piece of pipe designed to restrain the pipe against longitudinal movement. The longitudinal thrust from the pipe is transferred into the anchor block via a puddle flange clamped onto the pipe (for DICL pipes) or via a thrust collar welded to the pipe (for MSCL pipes). The pipeline will be anchored with appropriate anchors blocks of suitable weight at suitable spacing for the sufficient negative buoyancy to sink the pipeline and hold it in position on the seafloor. The Anchor block for submarine pipeline is designed according to Bureau of Indian Standards as per IS 5330:1984.

Typical Concrete Blocks



Concrete Blocks with HDPE Pipe

2.2. Types of Anchor Blocks

Depending upon the environmental condition and size of pipeline, the concrete anchor blocks can be moulded into rectangular, circular, hexagonal, octagonal shapes.


Circular Anchor Blocks


Rectangular Anchor Blocks

Octagonal Anchor Blocks

3. DESIGN OF ANCHOR BLOCKS

In order to keep the submarine pipeline intact with the seabed, the concrete anchor blocks are to be appropriately designed to counter the external forces acting on the pipeline viz., drag force, inertia force, lift force and buoyant force. The design of anchor blocks for HDPE pipeline was carried out using NEARCON Model an in-house computer model developed by Indomer Coastal Hydraulics (P) Ltd., Chennai. The design of anchor blocks in NEARCON Model utilizes the oceanographic conditions and the pipeline specifications as the required input.

This report presents the details of design considerations for anchor blocks of varying pipeline diameter.

Table 3.1. Design input consideration for anchor blocks

Outer Diameter (mm)	Shape of Anchor Block	Buoyancy	Deepwater Wave Height (m)	Water Depth (m)	Current Velocity (m/s)
160	Rectangular	50% 75 % 100 %	0.5	5	0.2
180					
200					
220					
250					
280					
310					
350					
400					
450					
500					
560	Circular	50% 75 % 100 %	1.0	5	0.2
630					
710					
800					
900					
1000					
1200	Octagonal	50% 75 % 100 %	1.0	5	0.2
1400					
1600					
1800					
2000					
2250					
2500					

NEARCON model:

```
*****************************************************************
PROGRAM NEARCON
*****************************************************************
* ESTIMATES THE FORCES ACTING ON THE SUBSEA PIPELINE AND
* WEIGHT OF CONCRETE BLOCK NEEDED TO STABILISE THE PIPELINE
* IN NEARSHORE WITHIN 5 METRE DEPTH.
*----------------------------------------------------------------
*-----DEFINITION OF VARIABLES USED-------------------------------
* DIA = DIAMETER OF PIPE (M)
* HNOT = DEEP WATER WAVE HEIGHT (M)
* HDASH = NET WAVE HEIGHT (M)
* TZ = ZERO CROSSING WAVE PERIOD (S)
* ALNOT = DEEP WATER WAVE DIRECTION (DEG)
* DEPTH = DEPTH AT WHICH THE PIPE IS LAID (M)
* CD = COEFFICIENT OF DRAG FORCE
* CM = COEFFICIENT OF INERTIAL FORCE
* CL = COEFFICIENT OF LIFT FORCE
* THETA = SLOPE OF SEABED (DEG)
* ANEW = KINEMATIC VISCOSITY OF SEA WATER (M2/S)
* REYN = REYNOLD'S NUMBER
* DIAH = DIAMETER OF CIRCULAR HOLE IN CONCRETE BLOCK
* BUY = PERCENTAGE OF BUOYANCY TO BE CONSIDERED FOR CALCULATION
*----------------------------------------------------------------
*-----OPENING INPUT & OUTPUT FILES-------------------------------
OPEN(10,FILE='NEARCON.DAT',ACCESS='SEQUENTIAL')
OPEN(20,FILE='NEARCON.RES')
*-----READING INPUT DATA-----------------------------------------
READ(10,*)DIA
READ(10,*)HNOT
READ(10,*)TZ
READ(10,*)ALNOT
READ(10,*)DEPTH
READ(10,*)CURVEL
READ(10,*)THETA
READ(10,*)CONTIK
READ(10,*)CONDIA
READ(10,*)CONLEN
READ(10,*)CONWID
READ(10,*)DIAH
READ(10,*)SOIL
READ(10,*)BUY
WRITE(*,*)'READING O.K.'
*-----INTIALISING------------------------------------------------
FMAX=0.
G=9.81
PI=3.141592
RAD=PI/180.
RHOSEA=1025.
*-----LOW RHOCON IS TAKEN TO ACCOUNT CUTS FOR BOLTS ETC.--------
RHOCON=2400.
ANEW=1.0*1E-5/10.764
*-----CALCULATION OF SHALLOW WATER KINEMATICS-------------------
EL=(G/(2.*PI))*TZ*TZ
HLNOT=DEPTH/EL
CNOT=(G/(2.*PI))*TZ
HL=HLNOT
IF(HLNOT.GE.0.5)GOTO 150
```

```
EL0=EL
33 EL1=EL
EL=EL0*TANH(2.*PI*DEPTH/EL1)
IF(ABS(EL1-EL).GT..0001)GO TO 33
HL=DEPTH/EL
150 GFAC1=2.*PI*HL
HYFAC=TANH(GFAC1)
CEL=CNOT*HYFAC
GFAC2=SINH(2.*GFAC1)
GFAC3=1.+(2.*GFAC1/GFAC2)
1
GFAC4=HYFAC*GFAC3
SC=SQRT(1./GFAC4)
ALFA=(CEL/CNOT)*SIN(ALNOT*RAD)
ALFA=ASIN(ALFA)
RC=SQRT(COS(ALNOT*RAD)/COS(ALFA))
ALFA=ALFA/RAD
HDASH=SC*RC*HNOT
SIGMA=(2.*PI)/TZ
AREA=(PI/4.)*DIA*DIA
*-----FORCE COEFFICIENTS (PAGE 42 MOUSSELLI)-------------------
ORBVEL=((HDASH*G*TZ)/(2.*EL))*COSH(GFAC1)
ACCN=(HDASH*G*PI)/(EL*COSH(GFAC1))
VEL= ABS(ORBVEL)+CURVEL
REYN=VEL*DIA/ANEW
IF(REYN.GE.50000.)GOTO 100
CD=1.3
CL=1.5
CM=2.0
GO TO 140
100 IF(REYN.GE.100000.)GO TO 110
CD=1.2
CL=1.0
CM=2.0
GO TO 140
110 IF(REYN.GE.250000.)GO TO 120
CD=1.53-(REYN/(3.*1E5))
CL=1.2-(REYN/(5.*1E5))
CM=2.0
GO TO 140
120 IF(REYN.GE.500000.)GO TO 130
CD=0.7
CL=0.7
CM=2.5-(REYN/(5*1E5))
GOTO 140
130 CD=0.7
CL=0.7
CM=1.5
*---- DRAG AND INERTIAL FORCE----------------------------------
140 FD=0.5*CD*RHOSEA*DIA*VEL*VEL
FI=CM*RHOSEA*ACCN*AREA
*-----LIFT FORCE ----------------------------------------------
FL=0.5*CL*RHOSEA*VEL*VEL*DIA
1000 CONTINUE
WRITE(20,420)FD/9.81
WRITE(20,430)FI/9.81
WRITE(20,440)FL/9.81
*-----BUOYANCY FORCE (GENERALLY 0.75 FILLED CONDITION)----222--------
BUOYF=AREA*1.*RHOSEA*G
```

```
* BUOYF=0.0*BUOYF
* BUOYF=0.25*BUOYF
* BUOYF=0.5*BUOYF
* BUOYF=0.75*BUOYF
* BUOYF=1.0*BUOYF
BUOYF=(BUY/100.)*BUOYF
WRITE(20,480)BUOYF/9.81
WRITE(*,480)BUOYF/9.81
*-----AMU=LATERAL FRICTION COEFFT. BET. PIPE SURFACE AND SEABED
2
IF(SOIL.EQ.1)AMU=0.6
IF(SOIL.EQ.2)AMU=0.7
IF(SOIL.EQ.3)AMU=0.5
*-----TOTAL FORCE----------------------------------------------
TOTFOR=(FD+FI+AMU*FL)/(AMU*COS(THETA*RAD)+SIN(THETA*RAD))
TOTFOR=TOTFOR+BUOYF
* WEIGTH OF PIPE NOT CONSIDERED AS HDPE NEUTRALLY BUOYANT--
* TOTFOR=TOTFOR-(WTPIPE*G)
WRITE(20,450)TOTFOR/9.81
*-----IMMERSED WEIGHT OF CONCRETE BLOCK -----------------------
*---------FOR CIRCULAR BLOCK----------------------------
IF(CONDIA.NE.0)THEN
VOLUM=(PI*(CONDIA**2-DIAH**2)/4.)*CONTIK
END IF
*-----FOR RECTANCULAR BLOCK----------------------------
IF(CONDIA.EQ.0)THEN
VOLUM=((CONLEN*CONWID)-(PI*DIAH**2.)/4.)*CONTIK
END IF
WRITE(20,451)VOLUM
WTAIR=VOLUM*RHOCON*G
WRITE(20,452)WTAIR/9.81
WEIGHT=VOLUM*(RHOCON-RHOSEA)*G
WRITE(20,470)WEIGHT/9.81
*-----SPACING OF CONCRETE BLOCK -------------------------------
SPACING=WEIGHT/TOTFOR
WRITE(20,460)SPACING
WRITE(20,475)BUY
420 FORMAT(5X,'DRAG FORCE (kg)',T40,'=',F12.3)
430 FORMAT(5X,'INERTIA FORCE (kg)',T40,'=',F12.3)
440 FORMAT(5X,'LIFT FORCE (kg)',T40,'=',F12.3)
450 FORMAT(5X,'TOTAL FORCE (kg)',T40,'=',F12.3)
451 FORMAT(5X,'VOLUME OF CONCRETE (m3)',T40,'=',F12.3)
452 FORMAT(5X,'WEIGHT OF CONCRETE IN AIR (kg)',T40,'=',F12.3)
480 FORMAT(5X,'BUOYANT FORCE (kg)',T40,'=',F12.3)
470 FORMAT(5X,'WT. OF CONC. IN WATER (kg)',T40,'=',F12.3)
460 FORMAT(5X,'SPACING (m)',T40,'=',F12.3)
475 FORMAT(5X,'BUOYANCY (%)',T40,'=',F12.3)
STOP
END
```

From the output of NEARCON model, the following conclusions have been arrived for the design of anchor blocks. The shape of anchor block with pipe diameter and appropriate buoyancy and oceanographic conditions adopted in design is described below.

3.1. Design of Rectangular Anchor Blocks

The anchor blocks for HDPE pipelines of 160 mm, 180 mm, 200 mm, 225 mm, 250 mm, 280 mm, 315 mm, 355 mm, 400 mm, 450 mm and 500 mm diameter have been designed for 50%, 75% and 100% buoyancy. The details of input parameters and output obtained for the mentioned pipeline diameters with 50%, 75% and 100% buoyancy are given in table 3.3, 3.4 and 3.5 respectively.

3.2. Design of Circular Anchor Blocks

The anchor blocks for HDPE pipelines of 500 mm, 560 mm, 630 mm, 710 mm, 800 mm, 900 mm and 1000 mm diameter have been designed for 50%, 75% and 100% buoyancy. The details of input parameters and output obtained for the mentioned pipeline diameters with 50%, 75% and 100% buoyancy are given in table 3.6, 3.7 and 3.8 respectively.

3.3. Design of Octagonal Anchor Blocks

The anchor blocks for HDPE pipelines of 1200 mm, 1400 mm, 1600 mm, 1800 mm and 2000 mm diameter have been designed for 50%, 75% and 100% buoyancy. The details of input parameters and output obtained for the mentioned pipeline diameters with 50%, 75% and 100% buoyancy are given in table 3.9, 3.10 and 3.11 respectively.

3.4. Calculation of pipeline size for different discharge

A continuity equation is an equation that describes the transport of some quantity. Using of this equation we will find the discharge. The details of input parameters given in table 3.2.

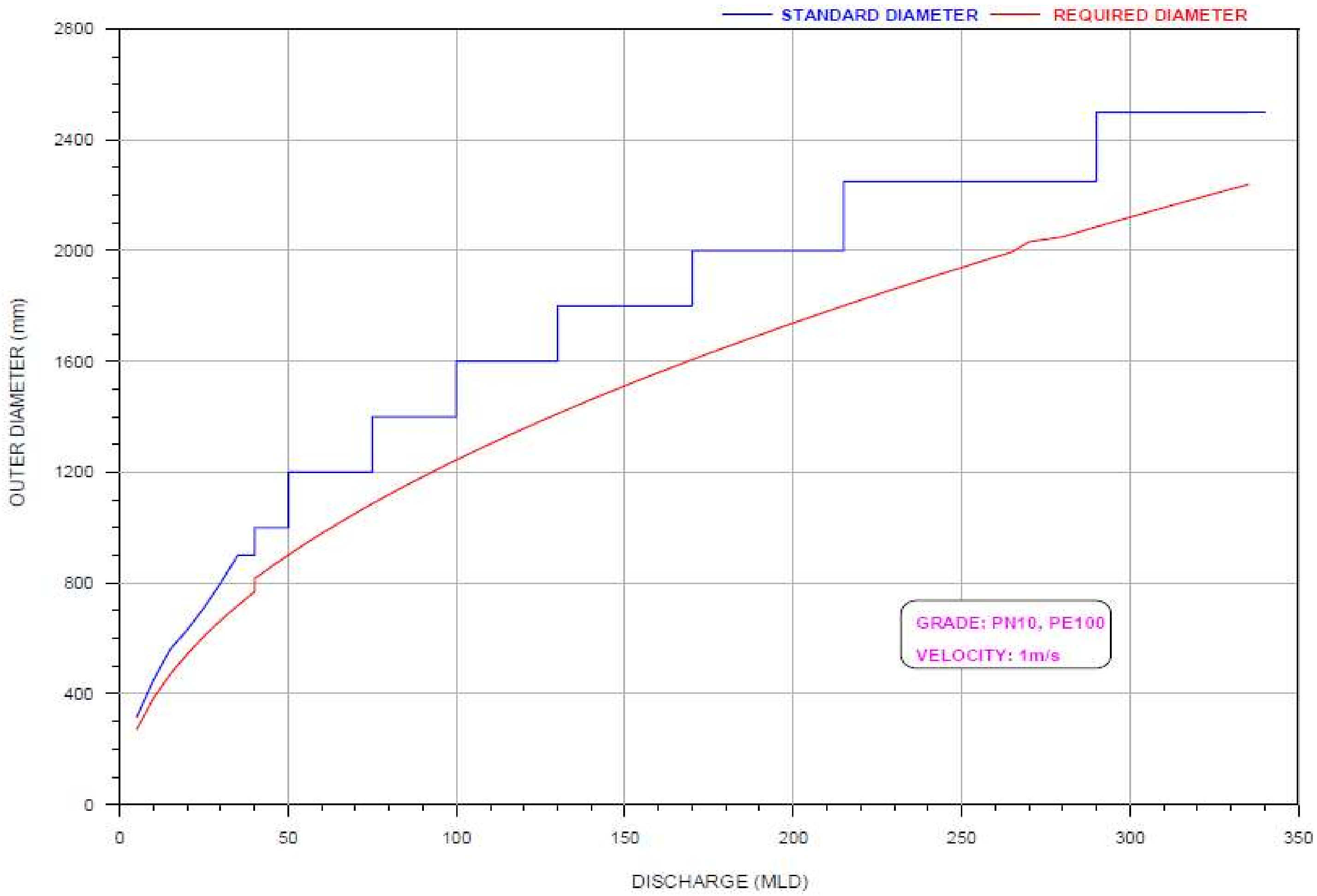
Table 3.2. Calculation of pipeline size for different discharge

Discharge (MLD)	Required Diameter (ID) mm	Wall Thickness (PN10, PE100, SDR 17)		Standard Diameter (OD) mm
		Min	Max	
5	272	16.6	18.4	315
10	384	23.7	26.2	450
15	470	29.7	32.8	560
20	543	33.2	36.7	630
25	607	37.4	41.3	710
30	665	42.1	46.5	800
35	718	47.4	52.3	900
40	768	47.4	52.3	900
45	815	53.3	58.8	1000
50	859	53.3	58.8	1000
55	901	53.3	58.8	1200
60	941	59.3	65.4	1200
65	979	59.3	65.4	1200
70	1016	67.9	74.8	1200
75	1052	67.9	74.8	1200
80	1086	67.9	74.8	1400
85	1119	67.9	74.8	1400
90	1152	67.9	74.8	1400
95	1184	67.9	74.8	1400
100	1214	82.4	90.8	1400
105	1244	82.4	90.8	1600
110	1274	82.4	90.8	1600
115	1302	82.4	90.8	1600
120	1330	82.4	90.8	1600
125	1358	82.4	90.8	1600
130	1384	82.4	90.8	1600
135	1411	94.1	103.7	1800
140	1437	94.1	103.7	1800
145	1462	94.1	103.7	1800
150	1487	94.1	103.7	1800
155	1512	94.1	103.7	1800
160	1536	94.1	103.7	1800
165	1560	94.1	103.7	1800
170	1583	94.1	103.7	1800
175	1606	105.9	116.6	2000
180	1629	105.9	116.6	2000
185	1652	105.9	116.6	2000
190	1674	105.9	116.6	2000
195	1696	105.9	116.6	2000
200	1717	105.9	116.6	2000
205	1739	105.9	116.6	2000
210	1760	105.9	116.6	2000
215	1780	105.9	116.6	2000
220	1801	105.9	116.6	2250
225	1821	117.6	129.5	2250
230	1842	117.6	129.5	2250
235	1861	117.6	129.5	2250

continued...

240	1881	117.6	129.5	2250
245	1901	117.6	129.5	2250
250	1920	117.6	129.5	2250
255	1939	117.6	129.5	2250
260	1958	117.6	129.5	2250
265	1977	117.6	129.5	2250
270	1995	117.6	129.5	2250
Discharge (MLD)	Required Diameter (ID) mm	Thickness (PN8, PE100, SDR 21)		Standard Diameter (OD) mm
		Min	Max	
280	2032	107.2	118.1	2250
285	2050	107.2	118.1	2250
290	2068	107.2	118.1	2250
295	2086	107.2	118.1	2500
300	2103	107.2	118.1	2500
305	2121	107.2	118.1	2500
310	2138	107.2	118.1	2500
315	2155	107.2	118.1	2500
320	2172	107.2	118.1	2500
325	2189	107.2	118.1	2500
330	2206	107.2	118.1	2500
335	2222	107.2	118.1	2500
340	2239	107.2	118.1	2500

Source: http://www.jains.com/Pipefittings/hdpe%20pipe.htm



Discharge vs Outer Diameter

Table 3.3. Design of Rectangular Anchor Blocks – 50% Buoyancy

Description	Unit	Input										
Outer diameter Pipe	m	0.16	0.18	0.20	0.22	0.25	0.28	0.31	0.35	0.40	0.45	0.50
Deep water wave height	m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1	1	1	1	1
Thickness of concrete block	m	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Length of concrete block	m	0.32	0.35	0.38	0.41	0.45	0.50	0.54	0.60	0.68	0.76	0.84
Width of concrete block	m	0.32	0.35	0.38	0.41	0.45	0.50	0.54	0.60	0.68	0.76	0.84
Diameter of hole	m	0.17	0.19	0.21	0.23	0.26	0.29	0.32	0.36	0.41	0.46	0.51
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	50	50	50	50	50	50	50	50	50	50	50
Description	Unit	Output										
Drag force	kg	4.55	4.89	5.18	5.43	5.70	5.86	5.90	6.15	7.03	7.91	8.79
Inertia force	kg	1.17	1.48	1.83	2.22	2.86	3.59	4.40	5.55	6.98	8.49	10.05
Lift force	kg	3.8	4.21	4.53	4.81	5.19	5.50	5.74	6.15	7.03	7.91	8.79
Buoyant force	kg	10.30	13.04	16.10	19.48	25.157	31.55	38.68	49.30	64.40	81.51	100.62
Total force	kg	22.056	26.04	30.31	34.850	42.17	50.11	58.66	71.647	90.81	112.10	100.62
Volume of concrete	m^3	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.09	0.12	0.15
Weight of concrete in air	kg	57.385	67.78	79.03	91.11	114.12	132.44	152.04	185.91	237.870	296.21	360.94
Weight of concrete in water	kg	32.87	38.83	45.27	52.20	65.38	75.87	87.11	106.51	136.280	169.70	206.79
Spacing	**c/c**	**1.50**	1.51	**1.50**	**1.50**	**1.55**	**1.51**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**
Buoyancy	%	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
Reference figure name	-	$^{50}R_{160}$	$^{50}R_{180}$	$^{50}R_{200}$	$^{50}R_{220}$	$^{50}R_{250}$	$^{50}R_{280}$	$^{50}R_{310}$	$^{50}R_{350}$	$^{50}R_{400}$	$^{50}R_{450}$	$^{50}R_{500}$

Table 3.4. Design of Rectangular Anchor Blocks – 75% Buoyancy

Description	Unit	Input										
Outer diameter Pipe	m	0.16	0.18	0.20	0.22	0.25	0.28	0.31	0.35	0.40	0.45	0.50
Deep water wave height	m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1	1	1	1	1
Thickness of concrete block	m	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Length of concrete block	m	0.35	0.38	0.42	0.45	0.50	0.55	0.60	0.67	0.76	0.85	0.94
Width of concrete block	m	0.35	0.38	0.42	0.45	0.50	0.55	0.60	0.67	0.76	0.85	0.94
Diameter of hole	m	0.17	0.19	0.21	0.23	0.26	0.29	0.32	0.35	0.41	0.46	0.51
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	100	100	100	100	100	100	100	100	100	100	100
Description	Unit	Output										
Drag force	kg	4.55	4.89	5.18	5.43	5.70	5.86	5.90	6.15	7.03	7.91	8.79
Inertia force	kg	1.17	1.48	1.83	2.22	2.86	3.59	4.40	5.55	6.98	8.49	10.05
Lift force	kg	3.8	4.21	4.53	4.81	5.19	5.50	5.74	6.15	7.03	7.91	8.79
Buoyant force	kg	15.45	19.56	24.15	29.22	37.73	47.33	58.02	73.96	96.60	122.26	150.94
Total force	kg	27.20	32.56	38.36	44.59	54.75	65.89	78.00	96.29	123.01	152.85	185.80
Volume of concrete	m^3	0.03	0.03	0.04	0.04	0.05	0.07	0.08	0.10	0.13	0.16	0.24
Weight of concrete in air	kg	71.85	83.55	102.07	115.88	141.77	170.24	201.29	249.92	320.81	400.54	489.10
Weight of concrete in water	kg	41.16	47.86	58.47	66.39	81.22	97.53	115.32	143.18	183.80	229.47	280.21
Spacing	**c/c**	**1.50**	**1.50**	**1.52**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**
Buoyancy	%	75	75	75	75	75	75	75	75	75	75	75
Reference figure name	-	$^{75}R_{160}$	$^{75}R_{180}$	$^{75}R_{200}$	$^{75}R_{220}$	$^{75}R_{250}$	$^{75}R_{280}$	$^{75}R_{310}$	$^{75}R_{350}$	$^{75}R_{400}$	$^{75}R_{450}$	$^{75}R_{500}$

Table 3.5. Design of Rectangular Anchor Blocks – 100% Buoyancy

Description	Unit	Input										
Outer diameter Pipe	m	0.16	0.18	0.20	0.22	0.25	0.28	0.31	0.35	0.40	0.45	0.50
Deep water wave height	m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1	1	1	1	1
Thickness of concrete block	m	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Length of concrete block	m	0.38	0.42	0.45	0.5	0.55	0.6	0.67	0.75	0.85	0.94	1.04
Width of concrete block	m	0.38	0.42	0.45	0.5	0.55	0.6	0.67	0.75	0.85	0.94	1.04
Diameter of hole	m	0.17	0.19	0.21	0.23	0.26	0.29	0.32	0.35	0.4	0.45	0.5
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	100	100	100	100	100	100	100	100	100	100	100
Description	**Unit**	**Output**										
Drag force	kg	4.55	4.89	5.18	5.43	5.70	5.86	5.90	6.15	7.03	7.91	8.79
Inertia force	kg	1.17	1.48	1.83	2.22	2.86	3.59	4.40	5.55	6.98	8.49	10.05
Lift force	kg	3.8	4.21	4.53	4.81	5.19	5.50	5.74	6.15	7.03	7.91	8.79
Buoyant force	kg	20.6	26.08	32.2	38.96	50.31	63.11	79.87	98.617	128.8	163.01	201.25
Total force	kg	32.36	39.08	46.41	54.33	67.33	81.66	100.09	120.95	155.21	193.61	236.11
Volume of concrete	m^3	0.03	0.04	0.05	0.06	0.07	0.08	0.11	0.13	0.17	0.21	0.26
Weight of concrete in air	kg	87.62	106.59	120.86	150.086	179.57	211.64	265.302	331.71	425.14	516.53	631.66
Weight of concrete in water	kg	50.202	61.06	69.24	85.98	102.88	121.25	151.996	190.04	243.57	295.93	361.89
Spacing	c/c	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Buoyancy	%	100	100	100	100	100	100	100	100	100	100	100
Reference figure name	-	$^{100}R_{160}$	$^{100}R_{180}$	$^{100}R_{200}$	$^{100}R_{220}$	$^{100}R_{250}$	$^{100}R_{280}$	$^{100}R_{310}$	$^{100}R_{350}$	$^{100}R_{400}$	$^{100}R_{450}$	$^{100}R_{500}$

Table 3.6. Design of Circular Anchor Blocks – 50% Buoyancy

Description	Unit	Input					
Outer diameter Pipe	m	0.56	0.63	0.71	0.80	0.90	1.0
Deep water wave height	m	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1
Thickness of concrete block	m	0.35	0.40	0.45	0.50	0.55	0.60
Diameter of concrete block	m	1.1	1.17	1.25	1.35	1.46	1.57
Diameter of hole	m	0.57	0.64	0.72	0.81	0.91	1.01
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	50	50	50	50	50	50
Description	**Unit**	**Output**					
Drag force	kg	28.8	32.4	36.5	41.2	46.3	51.5
Inertia force	kg	21.5	27.3	34.6	44.0	55.7	68.8
Lift force	kg	28.8	32.4	36.5	41.2	46.3	51.5
Buoyant force	kg	126.2	159.7	202.9	257.61	326.0	402.5
Total force	kg	224.6	274.7	337.9	416.6	513.6	620.5
Volume of concrete	m3	0.2	0.3	0.3	0.4	0.5	0.6
Weight of concrete in air	kg	583.9	723.2	885.6	1099.3	1351.3	1634.0
Wt. of conc. in water	kg	334.5	414.3	507.3	629.8	774.2	936.1
Spacing	c/c	1.50	1.50	1.50	1.50	1.50	1.50
Buoyancy	%	50	50	50	50	50	50
Reference figure name	-	$^{50}C_{560}$	$^{50}C_{630}$	$^{50}C_{710}$	$^{50}C_{800}$	$^{50}C_{900}$	$^{50}C_{1000}$

Table 3.7. Design of Circular Anchor Blocks – 75% Buoyancy

Description	Unit	Input					
Outer diameter Pipe	m	0.56	0.63	0.71	0.80	0.90	1.0
Deep water wave height	m	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1
Thickness of concrete block	m	0.37	0.42	0.47	0.53	0.58	0.63
Diameter of concrete block	m	1.18	1.26	1.35	1.45	1.56	1.68
Diameter of hole	m	0.57	0.64	0.72	0.81	0.91	1.01
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	75	75	75	75	75	75
Description	Unit	Output					
Drag force	kg	28.8	32.4	36.5	41.2	46.3	51.5
Inertia force	kg	21.5	27.3	34.6	44.0	55.7	68.8
Lift force	kg	28.8	32.4	36.5	41.2	46.3	51.5
Buoyant force	kg	189.3	239.6	304.3	386.4	489.0	603.7
Total force	kg	287.8	354.6	439.4	545.4	676.6	821.8
Volume of concrete	m3	0.3	0.3	0.4	0.6	0.7	0.8
Weight of concrete in air	kg	744.5	932.6	1155.3	1444.9	1755.2	2140.2
Wt. of conc. in water	kg	426.5	534.3	661.9	827.8	1005.6	1226.1
Spacing	c/c	1.5	1.5	1.5	1.5	1.5	1.5
Buoyancy	%	75	75	75	75	75	75
Reference figure name	-	$^{75}C_{560}$	$^{75}C_{630}$	$^{75}C_{710}$	$^{75}C_{800}$	$^{75}C_{900}$	$^{75}C_{1000}$

Table 3.8. Design of Circular Anchor Blocks – 100% Buoyancy

Description	Unit	Input					
Outer diameter Pipe	m	0.56	0.63	0.71	0.80	0.90	1.0
Deep water wave height	m	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1
Thickness of concrete block	m	0.39	0.45	0.49	0.54	0.60	0.64
Diameter of concrete block	m	1.25	1.32	1.43	1.55	1.67	1.80
Diameter of hole	m	0.57	0.64	0.72	0.81	0.91	1.01
Soil type	-	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	100	100	100	100	100	100
Description	UNIT	OUTPUT					
Drag force	kg	28.8	32.46	36.58	41.22	46.37	51.53
Inertia force	kg	21.5	27.30	34.68	44.03	55.73	68.80
Lift force	kg	28.8	32.46	36.58	41.22	46.37	51.53
Buoyant force	kg	252.4	319.51	405.81	515.22	652.07	805.03
Total force	kg	350.9	434.24	540.55	674.34	839.22	1023.07
Volume of concrete	m3	0.3	0.47	0.58	0.74	0.92	1.11
Weight of concrete in air	kg	909.8	1130.52	1409.9	1777.61	2217.61	2678.023
Wt. of conc. in water	kg	521.2	647.6	807.76	101842	1270.50	1534.28
Spacing	c/c	1.50	1.50	1.50	1.50	1.50	1.50
Buoyancy	%	100	100	100	100	100	100
Reference figure name	-	$^{100}C_{560}$	$^{100}C_{630}$	$^{100}C_{710}$	$^{100}C_{800}$	$^{100}C_{900}$	$^{100}C_{1000}$

Table 3.9. Design of Octagonal Anchor Blocks – 50% Buoyancy

Description	Unit	Input						
Outer diameter Pipe	m	1.20	1.40	1.60	1.80	2.0	2.250	2.5
Wave height	m	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1
Thickness of concrete block	m	0.61	0.64	0.70	0.78	0.82	0.87	1.0
Diameter of Concrete Block	m	1.85	2.12	2.35	2.56	2.80	3.1	3.32
Diameter of hole	m	1.21	1.41	1.61	1.81	2.01	2.26	2.51
Soil type (1=clay, 2=sand, 3=gravel)	-	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	50	50	50	50	50	50	50
Description	**Unit**	**Output**						
Drag force	kg	61.8	72.1	82.4	92.7	103.0	115.9	128.8
Inertia force	kg	99.0	134.8	176.1	222.9	275.2	348.3	430.0
Lift force	kg	61.8	72.14	82.4	92.7	103.0	115.9	128.8
Buoyant force	kg	579.6	788.9	1030.4	1304.15	1610.0	2037.7	2515.7
Total force	kg	864.2	1147.8	1471.3	1834.7	2237.9	2798.0	3420.5
Volume of concrete	m^3	0.9	1.2	1.61	2.0	2.4	3.0	3.7
Weight of concrete in air	kg	2251.8	3023.5	3866.5	4818.7	5873.3	7383.5	8901.3
Wt. of conc. in water	kg	1290.1	1732.2	2215.2	2760.7	3364.9	4230.1	5099.7
Spacing	c/c	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Buoyancy	%	50	50	50	50	50	50	50
Reference figure name	-	$^{50}O_{1200}$	$^{50}O_{1400}$	$^{50}O_{1600}$	$^{50}O_{1800}$	$^{50}O_{2000}$	$^{50}O_{2250}$	$^{50}O_{2500}$

Table 3.10. Design of Octagonal Anchor Blocks – 75% Buoyancy

Description	Unit	Input						
Outer diameter Pipe	m	1.20	1.40	1.60	1.80	2.0	2.250	2.5
Wave height	m	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1
Thickness of concrete block	m	0.63	0.65	0.71	0.81	0.86	0.92	1.1
Diameter of Concrete Block	m	2.0	2.30	2.55	2.75	3.0	3.3	3.5
Diameter of hole	m	1.21	1.41	1.61	1.81	2.01	2.26	2.51
Soil type (1=clay, 2=sand, 3=gravel)	-	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	75	75	75	75	75	75	75
Description	Unit	Output						
Drag force	kg	61.8	72.1	82.4	92.7	103.0	115.9	128.8
Inertia force	kg	99.0	134.8	176.1	222.9	275.2	348.3	430.0
Lift force	kg	61.8	72.1	82.4	92.7	103.0	115.9	128.8
Buoyant force	kg	869.4	1183.3	1545.6	1956.2	2415.0	3056.6	3773.5
Total force	kg	1154.1	1542.3	1986.6	2486.8	3043.0	3816.9	4678.3
Volume of concrete	m^3	1.25	1.6	2.1	2.7	3.5	4.1	5.1
Weight of concrete in air	kg	3011.4	4045.5	5233.3	6544.5	8040.3	10027.6	12336.8
Wt. of conc. in water	kg	1725.3	2317.7	2998.2	3749.4	4606.4	5744.9	7067.9
Spacing	c/c	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Buoyancy	%	75	75	75	75	75	75	75
Reference figure name	-	$^{75}O_{1200}$	$^{75}O_{1400}$	$^{75}O_{1600}$	$^{75}O_{1800}$	$^{75}O_{2000}$	$^{75}O_{2250}$	$^{75}O_{2500}$

Table 3.11. Design of Octagonal Anchor Blocks – 100% Buoyancy

Description	Unit	Input						
Outer diameter Pipe	m	1.20	1.40	1.60	1.80	2.0	2.250	2.5
Wave height	m	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Wave period	s	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Wave crest angle w.r.t. Pipeline	(deg.)	10	10	10	10	10	10	10
Water depth	m	5	5	5	5	5	5	5
Current velocity	m/s	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Slope of seabed	(deg.)	1	1	1	1	1	1	1
Thickness of concrete block	m	0.65	0.68	0.74	0.85	1.2	1.3	1.4
Diameter of Concrete Block	m	2.12	2.43	2.7	2.9	3.2	3.5	3.8
Diameter of hole	m	1.21	1.41	1.61	1.81	2.01	2.26	2.51
Soil type (1=clay, 2=sand, 3=gravel)		Sand	Sand	Sand	Sand	Sand	Sand	Sand
Buoyancy	%	100	100	100	100	100	100	100
Description	**Unit**	**Output**						
Drag force	kg	61.8	72.1	82.4	92.7	103.06	115.9	128.8
Inertia force	kg	99.0	134.8	176.1	222.9	275.2	348.3	430.0
Lift force	kg	61.8	72.1	82.4	92.7	103.0	115.9	128.8
Buoyant force	kg	1159.2	1577.8	2060.8	2608.3	3220.1	4075.4	5031.4
Total force	kg	1443.9	1936.8	2501.8	3138.8	3848.0	4835.8	5936.2
Volume of concrete	m^3	1.5	2.0	2.7	3.4	5.8	7.2	8.9
Weight of concrete in air	kg	3712.7	5020.4	6552.9	8225.5	14023.8	17502.0	21480.68
Wt. of conc. in water	kg	2127.1	2876.2	3754.2	4712.5	8034.4	10027.2	12306.64
Spacing	c/c	1.5	1.5	1.5	1.5	2.0	2.0	2.0
Buoyancy	%	100	100	100	100	100	100	100
Reference figure name	-	$^{100}O_{1200}$	$^{100}O_{1400}$	$^{100}O_{1600}$	$^{100}O_{1800}$	$^{100}O_{2000}$	$^{100}O_{2250}$	$^{100}O_{2500}$

4. TYPICAL ANCHOR BLOCKS

The shape of concrete blocks can be modified retaining with the indicated concrete block weight. Typical anchor blocks of rectangular, circular and octagonal shape are shown in Figs. 4.1, 4.2 and 4.3 respectively.

5. LAYING OF PIPELINE

The three types of pipelaying method commonly used for withdrawal of water.

- Open trench method
- Horizontal drilling method
- Trestle method

Open trench method

Open trench method, in this method suitable for all pipe diameters, open-trench pipe-laying is the most common method. Trench is excavated along the planned pipeline route. If the in-situ soil does not offer a suitable pipe bed, the trench is deepened and bedded. The pipes can then be lowered into the trench as a welded pipe string.

Horizontal drilling method

The horizontal drilling technique is used in trenchless pipeline construction and is particularly suitable for pipe-laying in densely built-up urban areas or for crossings underneath water or buildings. The pilot hole is drilled along a two- or three-dimensionally curved line between the entry point and an exit point. The in-situ soil is loosened by a drill head at the front end of the drill string. In the second step in controlled horizontal drilling, the pilot hole is widened. Finally, the pipe string is pulled in from the exit point into the widened borehole.

Trestle method

A pipe runs at a relatively higher elevation, usually calls for a 'trestle' support. For taller heights, with the pipe required to be supported at one elevation, a trestle is more economical when compared with a pipe-rack. Pipe trestle is essentially a lattice cantilever column with adequate radii of gyration about the 2 orthogonal axes. Design of a pipe trestle is usually governed by transverse loads from wind, earthquake, pipe friction and pipe anchors.

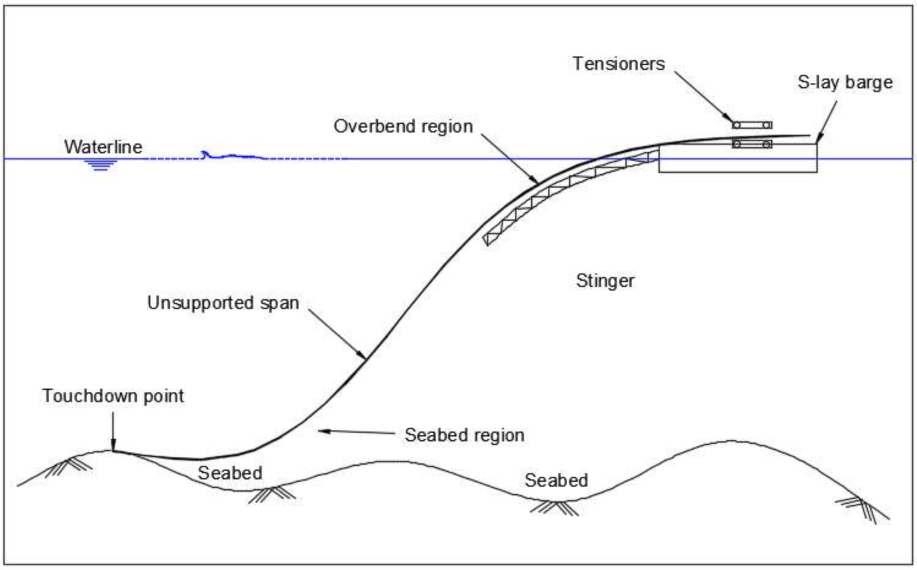
5.1. Laying of pipeline in offshore

Buoyancy affects the pipelay process, both in positive and negative ways. In the water, the pipe weighs less if it is filled with air, which puts less stress on the pipelay barge. But once in place on the seabed, the pipe requires a downward force to remain in place. This can be provided by the weight of the product passing through the pipeline, but gas does not weigh enough to keep the pipe from drifting across the seafloor. In shallow-water scenarios, concrete is poured over the pipe to keep it in place, while in Deepwater situations, the amount of insulation and the thickness required to ward of hydrostatic pressure is usually enough to keep the line in place.

- S-lay
- J-lay
- Reel lay

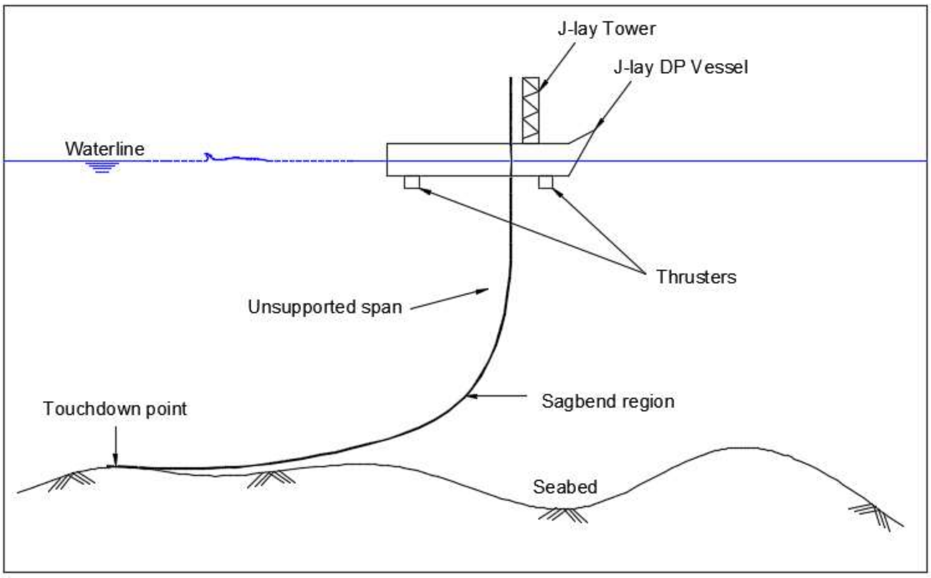
a) S-lay Method

The most common method of pipeline installation in shallow water is the S-lay method. In the S-lay method, the welded pipeline is supported on the rollers of the vessel and the stinger, forming the over-bend. Then it is suspended in the water all the way to the seabed, forming the sag-bend. The over-bend and sag-bend form the shape of an "S."



b) J-lay Method

J-lay method used in Deepwater oil and gas fields, the J-lay system for pipeline installation was invented. In this system, lengths of pipe are welded in a near vertical or vertical position and lowered to the seabed. In this configuration, the pipeline from the surface to the seabed is one large radius bend resulting in lower stresses than an S-lay system in the same water depth. There is no over-bend, and a large stinger required in S-lay to support the pipe in Deepwater is eliminated. The horizontal forces required to maintain this configuration are much smaller than required for an S-lay system. This lends itself for DP shipshape vessels and derrick barges to be equipped with a J-lay tower.



Normally, the J-lay process is slower than S-lay, but since the large J-lay towers are capable of handling prefabricated quad joints (160 feet long), the speed of pipe laying is increased. The J-lay method is normally used in water depths greater than 500 feet. These water depths are normally too great for moored lay vessels to operate, because the required tensions and pipe bending stresses are too large.

c) Reel-lay Method

Reel pipelay is a method of installing pipelines in the ocean from a giant reel mounted on an offshore vessel. The reeled pipeline can be installed in an S-lay method or J-lay method depending on the design of the reel vessel and the depth of water. Reel vessels can have vertical reels or horizontal reels.

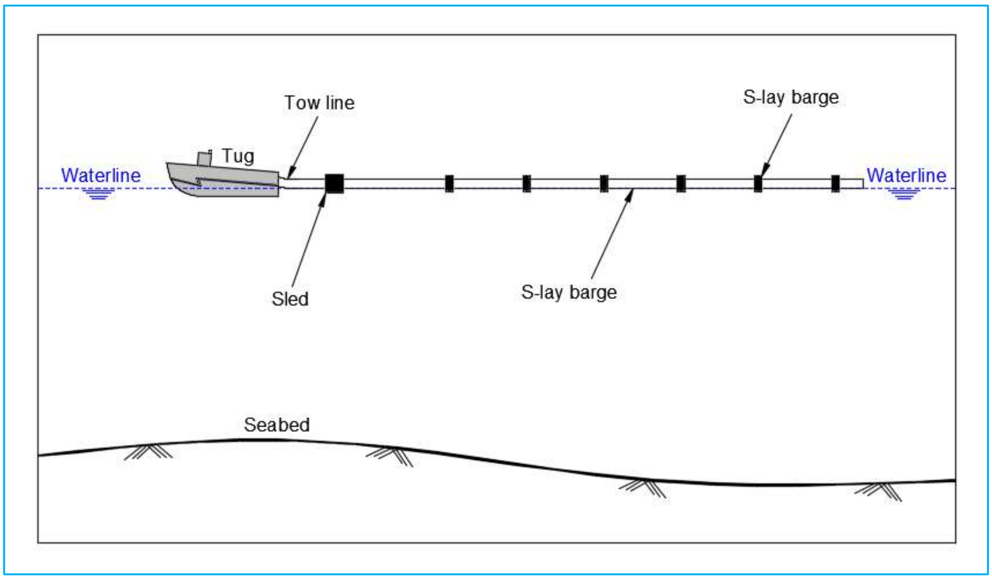
5.2. Pipeline Towing Method

Pipeline towing method is useful for bundled pipelines where several pipelines with different functions are packed together inside a large carrier pipe. The pipeline is constructed in a designed length onshore and towed into the sea.

- Surface towing method
- Mid depth towing method
- Bottom towing method

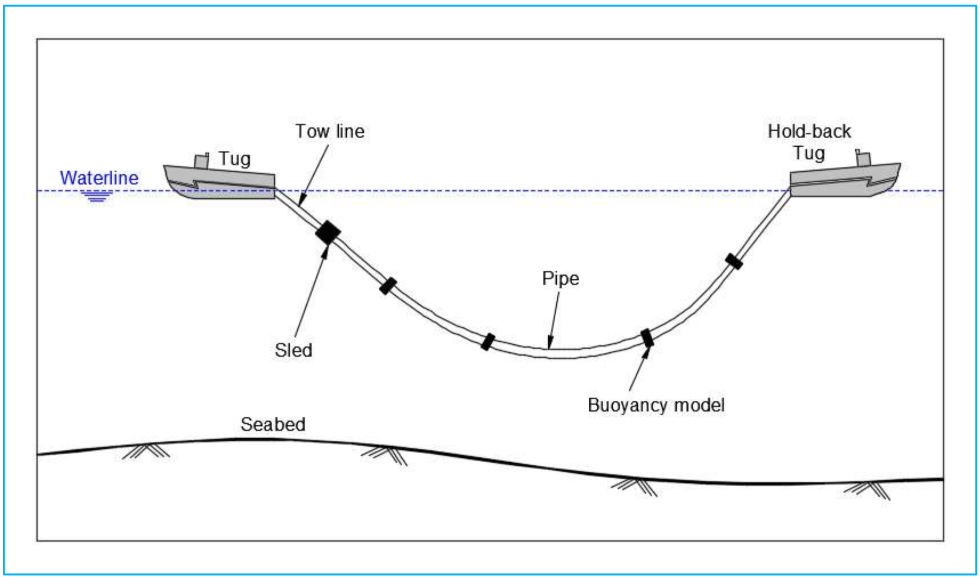
a) Surface towing method

Surface tow, buoyancy modules are installed at designed intervals so that the pipeline is floated, and the top of the pipe just breaks the surface. Two towing vessels are used to tow the pipeline. One is used to pull and another one is used to hold back, therefore the pipeline can be transported in a controlled manner. Strong weather conditions can damage the pipeline while it is being transported. Additionally, in a strong current condition, it is extremely difficult to accurately position the pipeline.



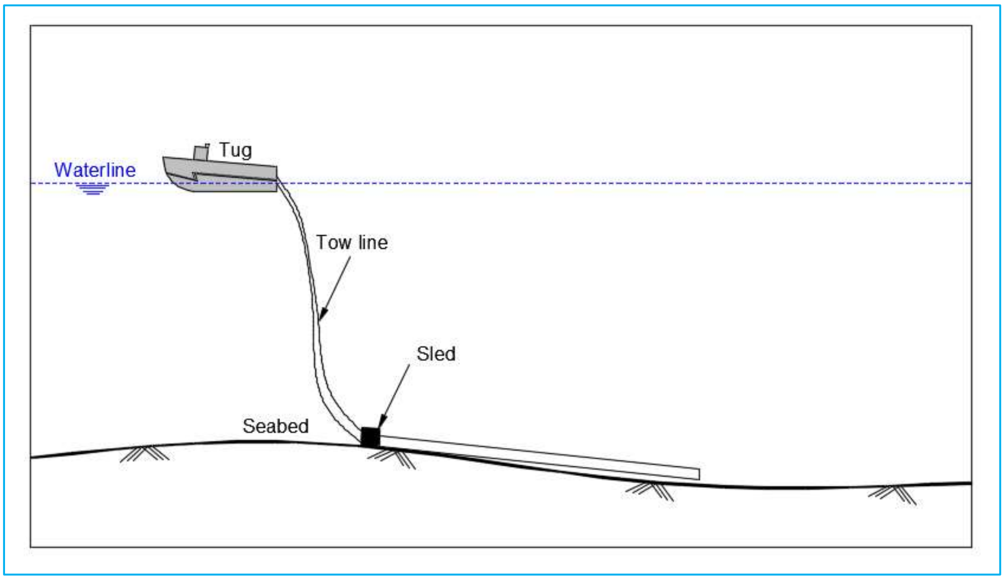
b) Mid depth tow method

The pipeline is not floated with this technique, and it submerses due to its weight or hanging chains on the pipeline at intervals. While the pipeline is being towed, the pipeline is suspended in a flat catenary between two vessels and proper tension to the pipeline must be maintained. One of the most critical parts is control of the submersed weight of the pipeline, which is roughly inversely proportional to the square of length of pipeline. Maximum length is about 5 km.



c) Bottom tow method

The pipeline is dragged on the bottom of sea, so the pipeline is not affected by currents. Before selecting this towing method, the seabed must be seriously surveyed to confirm the bottom area is suitable for towing. During the tow, it is very important to have survey as precisely as possible. Since the bottom part of the pipe will touch the seabed all the time, the outer protection of the pipeline can be damaged in some extent. Therefore, buoyancy modules can be installed to reduce submerged weight and friction force acting on the body of the pipeline.



GALLERY

Trestle Method

Laying of trestle

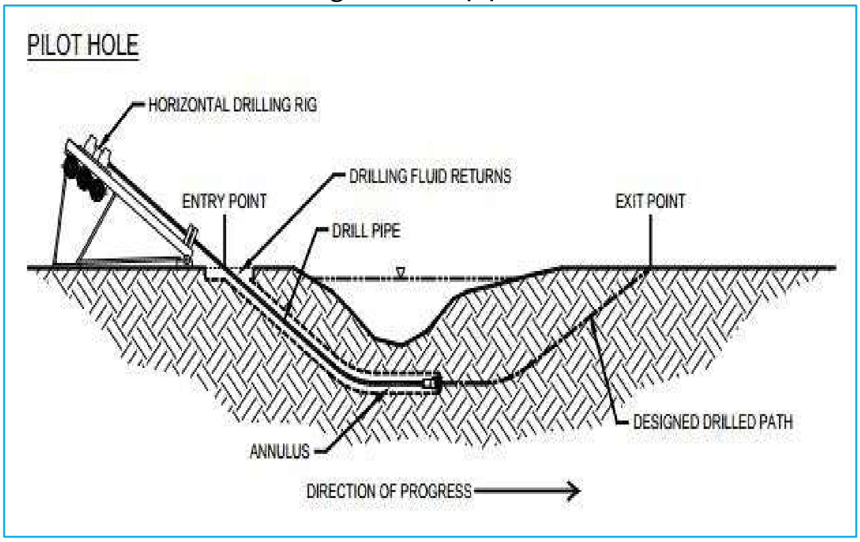
Construction of trestle

Alignment of trestle

Open trench and horizontal drilling method

Open trench method

Alignment of pipeline



Horizontal drilling method

GLOSSARY - BASIC DEFINITIONS

Drag force

A drag force is the resistance force caused by the motion of a body through a fluid. A drag force acts opposite to the direction of the oncoming flow velocity. This is the relative velocity between the body and the fluid.

Inertia force

Inertia force is defined as a force opposite in direction to an accelerating force acting on a body and equal to the product of the accelerating force and the mass of the body.

Lift force

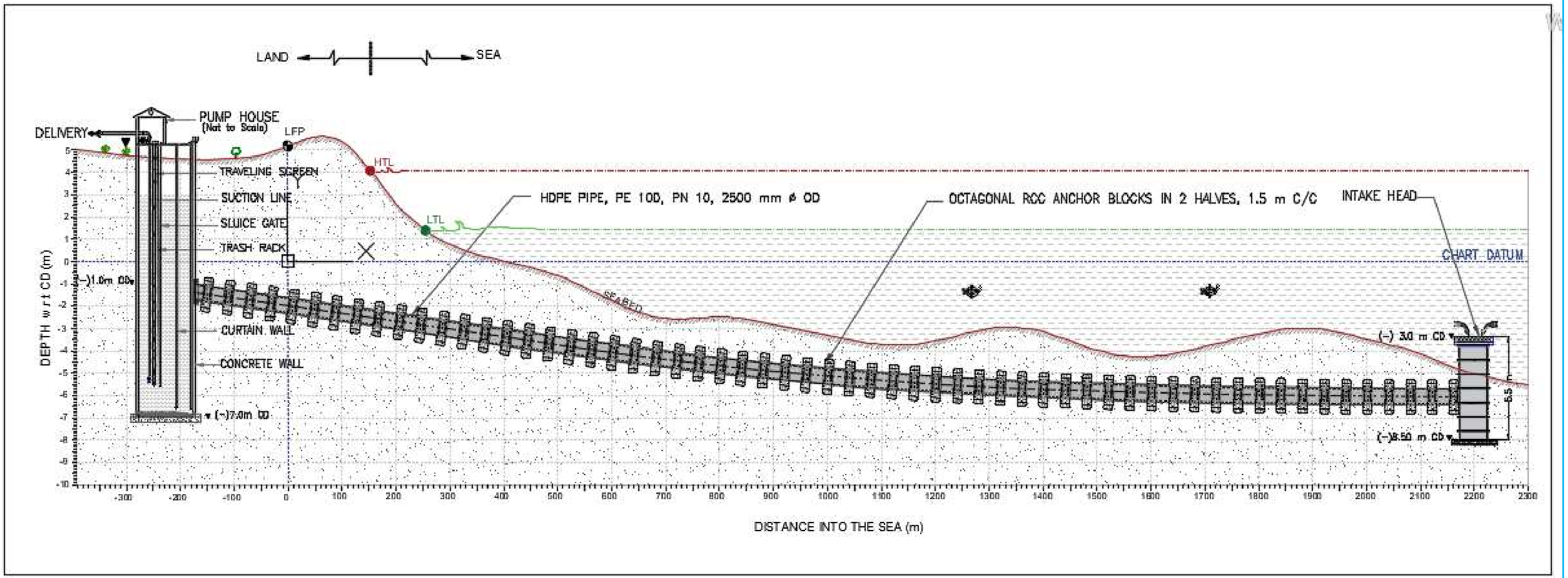
A fluid flowing around the surface of an object exerts a force on it. Lift is the component of this force that is perpendicular to the oncoming flow direction. It contrasts with the drag force, which is the component of the force parallel to the flow direction.

Buoyant force

Buoyancy or upthrust, is an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object. In a column of fluid, pressure increases with depth because of the weight of the overlying fluid.

buoyant force = weight of displaced fluid

Typical longitudinal intake system for pipeline



Typical longitudinal intake system for Trestle type pipeline