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LAMPIRAN

Lampiran 1. *Design Factor*

(ASME B31.8 *Gas Transmission and Distribution Piping System* Table 841.1.6-1*)*

Location Class	**Design Factor, F**
Location Class 1, Division 1	0.80
Location Class 1, Division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Lampiran 2. *Temperature*

ASME B31.8 *Gas Transmission and Distribution Piping System* Table 841.1.8-1*)*

Temperature, °F (°C)	**Temperature Derating Factor, F**
Location Class 1, Division 1	0.80
Location Class 1, Division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Lampiran 3. *Weld Joint Factor*

ASME B31.8 *Gas Transmission and Distribution Piping System* Table 841.1.7-1*)*

Spec. No	Pipe Class	*E* Factor
ASTM A53	Seamless	1.00
	Electric-resistance-welded	1.00
	Furnace-buttweld, continuous weld	0.60
ASTM A106	Seamless	1.00
ASTM A134	Electric-fusion-arc-welded	0.80
ASTM A135	Electric-resistance-welded	1.00
ASTM A139	Electric-fusion-arc-welded	0.80
ASTM A333	Seamless	1.00
	Electric-resistance-welded	1.00
ASTM A381	Submerged-arc-welded	1.00
ASTM A671	Electric-fusion-welded	
	Classes 13, 23, 33, 43, 51	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A672	Electric-fusion-welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A691	Electric-fusion-welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
API 5L	Electric welded	1.00
	Seamless	1.00
	Submerged-arc-welded (longitudinal seam or helical seam)	1.00
	Furnace-butwelded, continuous weld	0.60

Lampiran 4. Perhitungan *Pressure Containment* dan Tekanan Hidrostatik

Pressure Containment **Ketebalan Pipa** ***(Wall Thickness)***

t = (Pi - Pe) x D/2 x S x F x E x T

Pi = 6.5 MPa
Pe = 1.00 MPa
Guess Value (tn) = 4 mm

$$tcont = \frac{(6.5 - 1.0) \cdot 609.6}{2 \cdot 290 \cdot 0.80 \cdot 1.00 \cdot 1.00} = 7.226 \text{ mm}$$

1 Pascal = 1 N/m^2
1 Pascal = 0.000001 Megapascal
1 MPa = 1 N/mm2

Tekanan Hidrostatik

Ph = ρgh

$$1025 \cdot 9.8 \cdot 100 = 1.005 \cdot 10^{6} \text{ Pa}$$

$$1.005 \cdot 10^{6} \cdot 10^{-6} = 1.005 \text{ MPa}$$

$$1.005 \cdot 10^{6} \cdot 0.000145038 = 145.763$$

1.00

Tekanan eksternal yang diambil adalah tekanan hidrostatik

Collapse Due to External Pressure

$$2 \cdot 290 \cdot \left(\frac{7.2}{609.6}\right) = 6.85 \text{ MPa}$$

Py is nominal of yield Pressure at Collapse defined as
= 2 x S x (tn/D)

$$2 \cdot 2 \cdot 10^{6} \cdot \frac{\left(\frac{7.2}{609.6}\right)^{3}}{\left(1 - 0.3^{2}\right)} = 7.242 \text{ MPa}$$

Px is nominal of *Elastic Collapse Pressure so defined as*
= 2 x E x (tn/D)^3/(1-v^2)
Which is :
Poisson's Ratio of Steel = 0.27 - 0.30
Young Modulus = 2 x 10^6

Lampiran 5. Perhitungan Ketebalan Pipa *Collapse Due to External Pressure*

Sehingga nilai ***Collapse External Pressure*** adalah

$$\frac{6.85 \cdot 7.242}{\left(6.85^{2} + 7.242^{2}\right)^{0.5}} = 4.976 \text{ MPa}$$

Po : Tekanan Eksternal
Pi : Tekanan Internal
Fo : *Collapse Factor*
Pc : *Collapse Pressure of Pipe*

Required Wall Thickness bases ***External Pressure***

$$tcoll = \sqrt{4.976 \cdot 0.7 - 1.0} = 1.576 \text{ mm}$$

Lampiran 6. Perhitungan Ketebalan Pipa Berdasarkan *Bending Combination*

Wall Thickness based on Buckling caused by Bending Combination and External Pressure

Perhitungan ini berdasarkan API RP 1111 section 4.3.2.2, kombinasi regangan bending dan tekanan eksternal didefinisikan sebagai :

Collapse Reduction Factor

$(1+20\cdot 0.025)^{-1}=0.667$

Fc = F0/collapse reduction factor

$\frac{0.7}{0.625}=1.12$

<u>*pressure internal dan eksternal diperbaiki*</u>

Menurut DNV OS-F101, bahwa ovality tidak boleh kurang dari 0.5% dan lebih dari 3%

$$\frac{0.0461}{0.0507}+\left(\frac{14-1.00}{1.12\cdot 7.242}\right)=2.512$$

4.3.2.2 Buckling Due to Combined Bending and External Pressure

Combined bending strain and external pressure load should satisfy the following:

$$\frac{\varepsilon}{\varepsilon_b}+\frac{(P_o-P_i)}{f_c P_c}\le g(\delta) \qquad (13)$$

Lampiran 7. Perhitungan Ketebalan Pipa Berdasarkan *Propagation Buckling*

Propagation Buckling

Buckling merupakan definisi dari perubahan atau deformasi *(ovalling)* pada penampang pipa. Prinsip buckling adalah perambatan deformasi bentuk pada penampang melintang pipa yang memanjang dan merambat pada sepanjang pipa. Perambatan deformasi melintang pipa disebabkan oleh tekanan hidrostatik.

Dalam hal mendesain *propagation buckling* tidak boleh melebihi kriteria yang telah ditentukan dalam standar API RP 1111. *Propagation Buckling* didefinisikan sebagai :

Pbp = 24 S (t/D)^2.4

$$\boldsymbol{pbp} = 24\cdot 290\cdot 1\left(\frac{1.576}{609.6}\right)^{2.4}=0.004\text{ MPa}$$

...rdasarkan ***propagation buckling***

$$\left(\frac{0.004}{\cdot 290\cdot 0.80\cdot 1}\right)^{\frac{1}{2.4}}\cdot 609.9=1.68\text{ mm}$$

Lampiran 8. Ketebalan Total Minimum

Penetuan Ketebalan Pipa Total

Setelah nilai-nilai diatas telah didapatkan, selanjutnya ialah dengan mengambil nilai terbesar lalu ditambahkan dengan nilai korosi dan nilai fabrikasi.

treq-opr = treq + tcorr + tmill + tcons

$$7.2+3+1.08=11.28 \quad \text{mm}$$

Lampiran 9. Berat Terendam Pipa

Diameter Total Luar Pipa

Ds + 2tcorr + 2 tc

$$0.609+2\cdot 0.15748+2\cdot 0.488189=1.9$$

Diameter Dalam Pipa

Do - 2tst

$$0.609-0.01178=0.597$$

$$\text{Wst} = \frac{3.14}{4}\cdot 7850\left(1.9^2-0.597^2\right)9.8=1.965\cdot 10^5 \text{N/m}$$

$$\text{Wcorr}=\frac{3.14}{4}\cdot 900\left(\left(1.9+2\cdot 0.003\right)^2\cdot 0.6\right)^2=3.357\cdot 10^3 \quad \text{N/m}$$

$$\text{Wc}=\frac{3.14}{4}\cdot 2200\left(1.9+2\cdot 0.003+2\cdot 0.0124\right)^2-\left(1.9+2\cdot 0.003\right)^2=6.435\cdot 10^3 \quad 6.435\cdot 10^3\cdot 9.81=6.313\cdot 10^4 \text{ N/m}$$

$$\text{Wcont}= \quad 0.6^2\cdot 430\cdot 9.81=1.519\cdot 10^3 \quad \text{N/m}$$

$$\text{Fb} = \frac{3.14}{4}\left(0.609\right)^2\cdot 1025\cdot 9.8=2.925\cdot 10^3 \text{N/m}$$

Weight Submerged

Berat pipa terendam dapat dihitung berdasarkan material pipa yang diketahui. Berat pipa terendam terdistribusi secara merata sepanjang pipa, khususnya untuk pipa berat, akan sangat berpengaruh dalam penentuan on bottom stability dan perilakunya terhadap span.

Wst = berat baja diudara N/m

Wcorr = Berat lapisan anti karat di udara, N/m

Wc = Berat selimut beton di udara, N/m

Wcont = Berat pengisi pipa

Fb= Bouyancy per meter

Lampiran 10. Perhitungan Stabilitas Vertikal

Gaya Apung (B)
B = phi/4 x Rho air laut x (D luar baja + 2 x Tebal lapisan anti karat + 2 x tebal selimut beton)^2 x gravitaasi

Diasumsikan
tebal lapisan beton = 12.4 mm
tebal lapisan karat = 3 mm

$$\frac{3.14}{4} \cdot 1025 \cdot (0.609+2 \cdot 0.003+2 \cdot 0.0124)^2 \cdot 9.8 = 3.228 \cdot 10^3$$

$$0.003+0.0124=0.015$$

Berat terendam Pipa (Ws)
Ws = Wst + Wcorr + Wc + Wcont - B

$$1.965 \cdot 10^5 + 3.357 \cdot 10^3 + 6.313 \cdot 10^4 + 1.519 \cdot 10^3 - 3.228 \cdot 10^3 = 2.613 \cdot 10^5$$

Specific Gravity

$$\frac{(2.925 \cdot 10^5 + 3.228 \cdot 10^3)}{3.228 \cdot 10^3} = 91.613$$

Stabilitas Vertikal

$$\gamma_w \cdot \frac{b}{w_s + b} = \frac{\gamma_w}{s_g} \leq 1.00 \qquad (3.1)$$

$$1.1 \cdot \frac{2.925 \cdot 10^3}{2.613 \cdot 10^5 + 2.925 \cdot 10^3} = 0.012 \qquad \frac{1.1}{91.613} = 0.012$$

Sehingga memenuhi stabilitas vertikal <1.1

Jika probabilitas daya apung negatif yang cukup rendah tidak didokumentasikan, faktor keamanan γW = 1,1 diterapkan

Lampiran 11. Perhitungan Gelombang

LANGKAH 1

Sehingga, langkah pertama yang harus ditentukan adalah dengan mencari ***peak enhacement***, dengan rumus sebagai berikut

In lieu of other information, the peak-enhancement factor may be taken as:

$$\gamma = \begin{cases} 5.0 & \varphi \leq 3.6 \\ \exp(5.75 - 1.15\varphi) & 3.6 < \varphi < 5.0; \\ 1.0 & \varphi \geq 5.0 \end{cases} \qquad \varphi = \frac{T_p}{\sqrt{H_s}} \qquad (3.7)$$

Diketahui :	ω=	0.523333	rad/s
	Tp=	8.83	m/s
	Hs=	4.74	s
Sehingga	φ=	4.06	
	γ=	2.96	

njutnya yaitu mendapatkan konstanta *generalize-phillips*

unt is given by:

) (3.5)

Dengan,

Hs=		4.74	m/s	
Tp=		8.83	s	
ωp=	2π/Tp	0.71	rad/s	(Peak Wave Frequency)

Sehingga nilai konstanta *generalize-phillips*

α=	0.01284916	0.3125	1419.258431	0.1

LANGKAH 3

The spectral width parameter is given by:

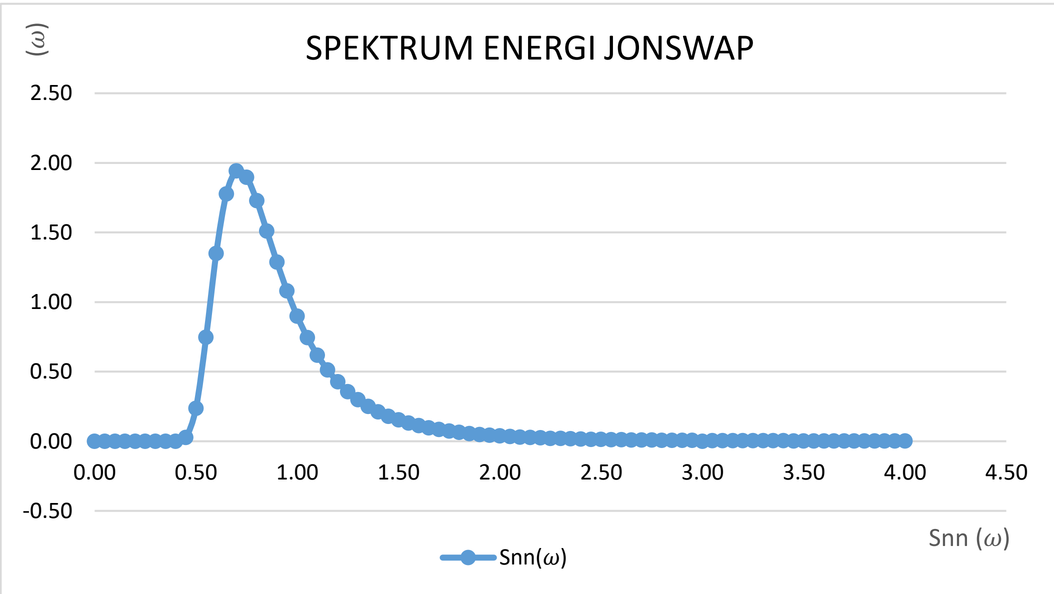
$$\sigma = \begin{cases} 0.07 & if\ \omega \le \omega_p \\ 0.09 & else \end{cases} \qquad (3.6)$$

ω=	0.52	rad/s
ωp=	0.71	rad/s
sehingga nilai σ adalah	σ=	0.07

ω	τ	Snn(ω)
0.00	0.07	0.00
0.05	0.07	0.00
0.10	0.07	0.00
0.15	0.07	0.00
0.20	0.07	0.00
0.25	0.07	0.00
0.30	0.07	0.00
0.35	0.07	0.00
0.40	0.07	0.00
0.45	0.07	0.03
0.50	0.07	0.24
0.55	0.07	0.75
0.60	0.07	1.35
0.65	0.07	1.78
0.70	0.07	1.94
0.75	0.07	1.90
0.80	0.07	1.73
0.85	0.07	1.51
0.90	0.07	1.29
0.95	0.07	1.08
1.00	0.07	0.90
1.05	0.07	0.74
1.10	0.07	0.62
1.15	0.07	0.51
1.20	0.07	0.43
1.25	0.07	0.36
1.30	0.07	0.30
1.35	0.07	0.25
1.40	0.09	0.21

1.45	0.09	0.18
1.50	0.09	0.15
1.55	0.09	0.13
1.60	0.09	0.11
1.65	0.09	0.10
1.70	0.09	0.08
1.75	0.09	0.07
1.80	0.09	0.06
1.85	0.09	0.06
1.90	0.09	0.05
1.95	0.09	0.04
2.00	0.09	0.04
2.05	0.09	0.03
2.10	0.09	0.03
2.15	0.09	0.03
2.20	0.09	0.02
2.25	0.09	0.02
2.30	0.09	0.02
2.35	0.09	0.02
2.40	0.09	0.02
2.45	0.09	0.01
2.50	0.09	0.01
2.55	0.09	0.01
2.60	0.09	0.01
2.65	0.09	0.01
2.70	0.09	0.01
2.75	0.09	0.01
2.80	0.09	0.01
2.85	0.09	0.01
2.90	0.09	0.01
2.95	0.09	0.01
3.00	0.09	0.00
3.05	0.09	0.00
3.10	0.09	0.00
3.15	0.09	0.00
3.20	0.09	0.00
3.25	0.09	0.00

3.30	0.09	0.00
3.35	0.09	0.00
3.40	0.09	0.00
3.45	0.09	0.00
3.50	0.09	0.00
3.55	0.09	0.00
3.60	0.09	0.00
3.65	0.09	0.00
3.70	0.09	0.00
3.75	0.09	0.00
3.80	0.09	0.00
3.85	0.09	0.00
3.90	0.09	0.00
3.95	0.09	0.00
4.00	0.09	0.00



ın menggunakan persamaan berikut
: number established by iteration from the transcendental equation:

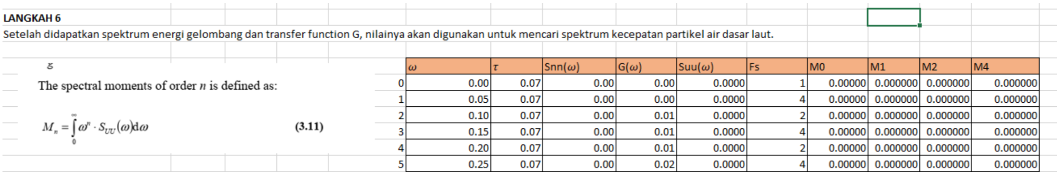
(3.10)

etode iterasi merupakan pengulangan dari variabel yang muncul. Diasumsikan nilai iterasi berjumlah satu dikalikan dengan kedalaman laut.

0.9971 0.03320856

k asumsi	d	g	ω	kx .d	tanh(kx d)	k	error
0.0279182	100	9.81	0.523333	2.791822	0.99251	0.02813	-1%
0.0281289	100	9.81	0.523333	2.81289	0.99282	0.02833	-1%
0.0283324	100	9.81	0.523333	2.833237	0.99310	0.02853	-1%
0.0285291	100	9.81	0.523333	2.852911	0.99337	0.02872	-1%
0.0287196	100	9.81	0.523333	2.871955	0.99362	0.02890	-1%
0.0289041	100	9.81	0.523333	2.890408	0.99385	0.02908	-1%
0.0290830	100	9.81	0.523333	2.908304	0.99406	0.02926	-1%
0.0292568	100	9.81	0.523333	2.925675	0.99426	0.02943	-1%
0.0294255	100	9.81	0.523333	2.942552	0.99445	0.02959	-1%
0.0295896	100	9.81	0.523333	2.958962	0.99463	0.02975	-1%
0.0297493	100	9.81	0.523333	2.974929	0.99480	0.02990	-1%
0.0299048	100	9.81	0.523333	2.990476	0.99496	0.03006	-1%
0.0300562	100	9.81	0.523333	3.005624	0.99511	0.03020	0%
0.0302039	100	9.81	0.523333	3.020394	0.99525	0.03035	0%
0.0303480	100	9.81	0.523333	3.034804	0.99539	0.03049	0%
0.0304887	100	9.81	0.523333	3.04887	0.99551	0.03063	0%
0.0306261	100	9.81	0.523333	3.062608	0.99564	0.03076	0%
0.0307603	100	9.81	0.523333	3.076033	0.99575	0.03089	0%
0.0308916	100	9.81	0.523333	3.08916	0.99586	0.03102	0%
0.0310200	100	9.81	0.523333	3.101999	0.99597	0.03115	0%
0.0311457	100	9.81	0.523333	3.114565	0.99607	0.03127	0%
0.0312687	100	9.81	0.523333	3.126868	0.99616	0.03139	0%
0.0313892	100	9.81	0.523333	3.138919	0.99625	0.03151	0%
0.0315073	100	9.81	0.523333	3.150727	0.99634	0.03162	0%
0.0316230	100	9.81	0.523333	3.162303	0.99642	0.03174	0%
0.0317366	100	9.81	0.523333	3.173655	0.99650	0.03185	0%
0.0318479	100	9.81	0.523333	3.184792	0.99658	0.03196	0%
0.0319572	100	9.81	0.523333	3.195721	0.99665	0.03206	0%
0.0320645	100	9.81	0.523333	3.20645	0.99672	0.03217	0%
0.0321699	100	9.81	0.523333	3.216986	0.99679	0.03227	0%
0.0322734	100	9.81	0.523333	3.227336	0.99686	0.03238	0%
[illegible]	[illegible]	9.81	0.523333	3.237506	0.99692	0.03248	0%
[illegible]	[illegible]	9.81	0.523333	3.247502	0.99698	0.03257	0%
[illegible]	[illegible]	9.81	0.523333	3.257331	0.99704	0.03267	0%
[illegible]	[illegible]	9.81	0.523333	3.266997	0.99710	0.03277	0%
[illegible]	[illegible]	9.81	0.523333	3.276506	0.99715	0.03286	0%
[illegible]	[illegible]	9.81	0.523333	3.285863	0.99721	0.03295	0%

0.0329507	100	9.81	0.523333	3.295072	0.99726	0.03304	0%
0.0330414	100	9.81	0.523333	3.304138	0.99731	0.03313	0%
0.0331307	100	9.81	0.523333	3.313066	0.99735	0.03322	0%
0.0332186	100	9.81	0.523333	3.321859	0.99740	0.03331	0%
0.0333052	100	9.81	0.523333	3.330522	0.99744	0.03339	0%



LANGKAH 6

Setelah didapatkan spektrum energi gelombang dan transfer function G, nilainya akan digunakan untuk mencari spektrum kecepatan partikel air dasar laut.

The spectral moments of order n is defined as:

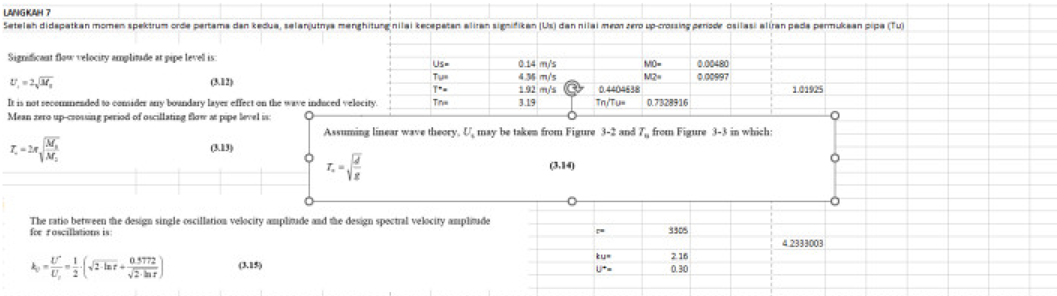
$$M_n = \int_0^\infty \omega^n \cdot S_{UU}(\omega) d\omega \qquad (3.11)$$

	ω	τ	Snn(ω)	G(ω)	Suu(ω)	Fs	M0	M1	M2	M4
0	0.00	0.07	0.00	0.00	0.0000	1	0.00000	0.000000	0.000000	0.000000
1	0.05	0.07	0.00	0.00	0.0000	4	0.00000	0.000000	0.000000	0.000000
2	0.10	0.07	0.00	0.01	0.0000	2	0.00000	0.000000	0.000000	0.000000
3	0.15	0.07	0.00	0.01	0.0000	4	0.00000	0.000000	0.000000	0.000000
4	0.20	0.07	0.00	0.01	0.0000	2	0.00000	0.000000	0.000000	0.000000
5	0.25	0.07	0.00	0.02	0.0000	4	0.00000	0.000000	0.000000	0.000000

ω	τ	Snn(ω)	G(ω)	Suu(ω)	Fs	M0	M1	M2	M4
0.00	0.07	0.00	0.00	0.0000	1	0.00000	0.000000	0.000000	0.000000
0.05	0.07	0.00	0.00	0.0000	4	0.00000	0.000000	0.000000	0.000000
0.10	0.07	0.00	0.01	0.0000	2	0.00000	0.000000	0.000000	0.000000
0.15	0.07	0.00	0.01	0.0000	4	0.00000	0.000000	0.000000	0.000000
0.20	0.07	0.00	0.01	0.0000	2	0.00000	0.000000	0.000000	0.000000
0.25	0.07	0.00	0.02	0.0000	4	0.00000	0.000000	0.000000	0.000000
0.30	0.07	0.00	0.02	0.0000	2	0.00000	0.000000	0.000000	0.000000
0.35	0.07	0.00	0.03	0.0000	4	0.00000	0.000000	0.000000	0.000000
0.40	0.07	0.00	0.03	0.0000	2	0.00000	0.000000	0.000000	0.000000
0.45	0.07	0.03	0.03	0.0000	4	0.00011	0.000013	0.000023	0.000005
0.50	0.07	0.24	0.04	0.0003	2	0.00061	0.000152	0.000152	0.000038
0.55	0.07	0.75	0.04	0.0012	4	0.00463	0.000637	0.001401	0.000424
0.60	0.07	1.35	0.04	0.0025	2	0.00498	0.001495	0.001793	0.000646
0.65	0.07	1.78	0.05	0.0039	4	0.01541	0.002504	0.006510	0.002750
0.70	0.07	1.94	0.05	0.0049	2	0.00977	0.003419	0.004786	0.002345
0.75	0.07	1.90	0.05	0.0055	4	0.02190	0.004106	0.012318	0.006929
0.80	0.07	1.73	0.06	0.0057	2	0.01136	0.004542	0.007267	0.004651
0.85	0.07	1.51	0.06	0.0056	4	0.02240	0.004760	0.016184	0.011693
0.90	0.07	1.29	0.06	0.0053	2	0.01069	0.004812	0.008662	0.007016
0.95	0.07	1.08	0.07	0.0050	4	0.01999	0.004748	0.018044	0.016285
1.00	0.07	0.90	0.07	0.0046	2	0.00922	0.004609	0.009219	0.009219
1.05	0.07	0.74	0.08	0.0042	4	0.01686	0.004425	0.018584	0.020488
[illegible]	[illegible]	[illegible]	0.08	0.0038	2	0.00767	0.004216	0.009275	0.011222
[illegible]	[illegible]	[illegible]	0.08	0.0035	4	0.01390	0.003997	0.018386	0.024315
[illegible]	[illegible]	[illegible]	0.09	0.0031	2	0.00630	0.003777	0.009066	0.013054
[illegible]	[illegible]	[illegible]	0.09	0.0029	4	0.01140	0.003563	0.017815	0.027836
[illegible]	[illegible]	[illegible]	0.09	0.0026	2	0.00517	0.003357	0.008729	0.014753
[illegible]	[illegible]	[illegible]	0.10	0.0023	4	0.00937	0.003163	0.017078	0.031125

1.40	0.09	0.21	0.10	0.0021	2	0.00426	0.002980	0.008343	0.016353
1.45	0.09	0.18	0.10	0.0019	4	0.00775	0.002808	0.016288	0.034247
1.50	0.09	0.15	0.11	0.0018	2	0.00353	0.002649	0.007946	0.017878
1.55	0.09	0.13	0.11	0.0016	4	0.00645	0.002500	0.015499	0.037237
1.60	0.09	0.11	0.11	0.0015	2	0.00295	0.002362	0.007558	0.019348
1.65	0.09	0.10	0.12	0.0014	4	0.00541	0.002234	0.014742	0.040134
1.70	0.09	0.08	0.12	0.0012	2	0.00249	0.002115	0.007189	0.020778
1.75	0.09	0.07	0.13	0.0011	4	0.00458	0.002004	0.014028	0.042962
1.80	0.09	0.06	0.13	0.0011	2	0.00211	0.001901	0.006845	0.022178
1.85	0.09	0.06	0.13	0.0010	4	0.00390	0.001806	0.013364	0.045739
1.90	0.09	0.05	0.14	0.0009	2	0.00181	0.001717	0.006526	0.023557
1.95	0.09	0.04	0.14	0.0008	4	0.00335	0.001635	0.012750	0.048482
2.00	0.09	0.04	0.14	0.0008	2	0.00156	0.001558	0.006230	0.024922
2.05	0.09	0.03	0.15	0.0007	4	0.00290	0.001486	0.012184	0.051202
2.10	0.09	0.03	0.15	0.0007	2	0.00135	0.001419	0.005959	0.026278
2.15	0.09	0.03	0.15	0.0006	4	0.00252	0.001356	0.011663	0.053910
2.20	0.09	0.02	0.16	0.0006	2	0.00118	0.001298	0.005709	0.027632
2.25	0.09	0.02	0.16	0.0006	4	0.00221	0.001243	0.011184	0.056619
2.30	0.09	0.02	0.16	0.0005	2	0.00104	0.001191	0.005480	0.028989
2.35	0.09	0.02	0.17	0.0005	4	0.00195	0.001143	0.010745	0.059340
2.40	0.09	0.02	0.17	0.0005	2	0.00091	0.001098	0.005270	0.030355
2.45	0.09	0.01	0.18	0.0004	4	0.00172	0.001055	0.010344	0.062087
2.50	0.09	0.01	0.18	0.0004	2	0.00081	0.001016	0.005078	0.031737
2.55	0.09	0.01	0.18	0.0004	4	0.00153	0.000978	0.009977	0.064875
2.60	0.09	0.01	0.19	0.0004	2	0.00073	0.000943	0.004903	0.033145
2.65	0.09	0.01	0.19	0.0003	4	0.00137	0.000910	0.009644	0.067724
2.70	0.09	0.01	0.19	0.0003	2	0.00065	0.000879	0.004745	0.034590
2.75	0.09	0.01	0.20	0.0003	4	0.00124	0.000849	0.009343	0.070658
2.80	0.09	0.01	0.20	0.0003	2	0.00059	0.000822	0.004602	0.036083
2.85	0.09	0.01	0.20	0.0003	4	0.00112	0.000796	0.009074	0.073705
2.90	0.09	0.01	0.21	0.0003	2	0.00053	0.000772	0.004476	0.037641
2.95	0.09	0.01	0.21	0.0003	4	0.00102	0.000749	0.008836	0.076899
3.00	0.09	0.01	0.21	0.0002	2	0.00048	0.000727	0.004365	0.039282
3.05	0.09	0.00	0.22	0.0002	4	0.00093	0.000707	0.008630	0.080283
3.10	0.09	0.00	0.22	0.0002	2	0.00044	0.000689	0.004270	0.041031
[illegible]	[illegible]	[illegible]	0.23	0.0002	4	0.00085	0.000671	0.008456	0.083908
[illegible]	[illegible]	[illegible]	0.23	0.0002	2	0.00041	0.000655	0.004191	0.042914
[illegible]	[illegible]	[illegible]	0.23	0.0002	4	0.00079	0.000640	0.008315	0.087831
[illegible]	[illegible]	[illegible]	0.24	0.0002	2	0.00038	0.000626	0.004129	0.044963
[illegible]	[illegible]	[illegible]	0.24	0.0002	4	0.00073	0.000613	0.008209	0.092124
[illegible]	[illegible]	[illegible]	0.24	0.0002	2	0.00035	0.000601	0.004085	0.047217

3.45	0.09	0.00	0.25	0.0002	4	0.00068	0.000590	0.008138	0.096868
3.50	0.09	0.00	0.25	0.0002	2	0.00033	0.000580	0.004059	0.049719
3.55	0.09	0.00	0.25	0.0002	4	0.00064	0.000571	0.008106	0.102156
3.60	0.09	0.00	0.26	0.0002	2	0.00031	0.000563	0.004052	0.052519
3.65	0.09	0.00	0.26	0.0002	4	0.00061	0.000556	0.008114	0.108095
3.70	0.09	0.00	0.27	0.0001	2	0.00030	0.000550	0.004067	0.055673
3.75	0.09	0.00	0.27	0.0001	4	0.00058	0.000544	0.008164	0.114805
3.80	0.09	0.00	0.27	0.0001	2	0.00028	0.000540	0.004103	0.059244
3.85	0.09	0.00	0.28	0.0001	4	0.00056	0.000536	0.008259	0.122416
3.90	0.09	0.00	0.28	0.0001	2	0.00027	0.000534	0.004162	0.063302
3.95	0.09	0.00	0.28	0.0001	4	0.00054	0.000532	0.008401	0.131072
4.00	0.09	0.00	0.29	0.0001	1	0.00013	0.000531	0.002122	0.033960
					Jumlah	0.28786	0.123116	0.598213	3.071462
					M	0.00480	0.00205	0.00997	0.05119



LANGKAH 7

Setelah didapatkan momen spektrum orde pertama dan kedua, selanjutnya menghitung nilai kecepatan aliran signifikan (Us) dan nilai *mean zero up-crossing periode* osilasi aliran pada permukaan pipa (Tu)

Significant flow velocity amplitude at pipe level is:

$$U_s = 2\sqrt{M_0} \quad (3.12)$$

It is not recommended to consider any boundary layer effect on the wave induced velocity.

Mean zero up-crossing period of oscillating flow at pipe level is:

$$T_u = 2\pi\sqrt{\frac{M_0}{M_2}} \quad (3.13)$$

Assuming linear wave theory, U_s may be taken from Figure 3-2 and T_u from Figure 3-3 in which:

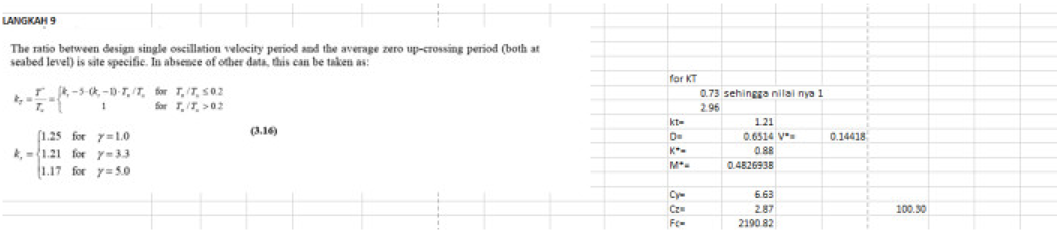
$$T_n = \sqrt{\frac{d}{g}} \quad (3.14)$$

Us=	0.14 m/s		M0=	0.00480		
Tu=	4.36 m/s		M2=	0.00997		
T*=	1.92 m/s	0.4404638				1.01925
Tn=	3.19	Tn/Tu=	0.7328916			

The ratio between the design single oscillation velocity amplitude and the design spectral velocity amplitude for τ oscillations is:

$$k_U = \frac{U^*}{U_s} = \frac{1}{2}\cdot\left(\sqrt{2\cdot\ln\tau} + \frac{0.5772}{\sqrt{2\cdot\ln\tau}}\right) \quad (3.15)$$

r=	3305	
		4.2333003
ku=	2.16	
U*=	0.30	



LANGKAH 9

The ratio between design single oscillation velocity period and the average zero up-crossing period (both at seabed level) is site specific. In absence of other data, this can be taken as:

$$k_T = \frac{T^*}{T_u} = \begin{cases} k_t - 5\cdot(k_t - 1)\cdot T_n/T_u & \text{for } T_n/T_u \le 0.2 \\ 1 & \text{for } T_n/T_u > 0.2 \end{cases} \quad (3.16)$$

$$k_t = \begin{cases} 1.25 & \text{for } \gamma = 1.0 \\ 1.21 & \text{for } \gamma = 3.3 \\ 1.17 & \text{for } \gamma = 5.0 \end{cases}$$

for KT				
0.73	sehingga nilai nya 1			
2.96				
kt=	1.21			
D=	0.6514	V*=	0.14418	
K*=	0.88			
M*=	0.4826938			
Cy=	6.63			
Cz=	2.87			100.30
Fc=	2190.82			

Lampiran 12. Perhitungan Arus

The current velocity may be reduced to take account of the effect of the bottom boundary layer and directionality:

$$V(z) = V(z_r)\cdot\frac{\ln(z+z_0)-\ln z_0}{\ln(z_r+z_0)-\ln z_0}\cdot\sin\theta_c \qquad (3.2)$$

Table 3-1 Seabed roughness

Seabed	Grain size d_{50} [mm]	Roughness z_0 [m]
Silt and clay	0.0625	$\approx 5\cdot10^{-6}$
Fine sand	0.25	$\approx 1\cdot10^{-5}$
Medium sand	0.5	$\approx 4\cdot10^{-5}$
Coarse sand	1.0	$\approx 1\cdot10^{-4}$
Gravel	4.0	$\approx 3\cdot10^{-4}$
Pebble	25	$\approx 2\cdot10^{-3}$
Cobble	125	$\approx 1\cdot10^{-2}$
Boulder	500	$\approx 4\cdot10^{-2}$

For a clayey seabed the seabed roughness parameter of silt should be used.
The mean perpendicular current velocity over a pipe diameter applies:

yang diambil adalah silt and clay

d50=	0.0625		
roughness=	0.000005		
z=	0.3257		0.000005
θ=	0.893997	0.893997	
zr=	1500.0%	0.15	
11.08430943			
10.30898599			
1.075208506			
V*=	0.144185		

Lampiran 13. Perhitungan Tanah

Load reduction due to pipe soil interaction

The hydrodynamic loads may be reduced due:

- a permeable seabed $r_{perm,i}$
- pipe penetrating the seabed $r_{pen,i}$ and/or trenching $r_{trench,i}$

Total load reduction is then:

$$r_{tot,i} = r_{perm,i}\cdot r_{pen,i}\cdot r_{tr,i} \qquad (3.17)$$

D= diameter of pipeline with adding concrete thickness and corrosion

Su= 7000 (clay)

Fc= 2190.82

Diketahui :

Gc= $\dfrac{7000}{0.6154\cdot 18000} = 0.632$

z= D/2 $\dfrac{0.6514}{2} = 0.326$

Kc= $\dfrac{7000\cdot 0.6154}{2190.82} = 1.966$

zpi= $0.0071\cdot\left(\dfrac{0.181^{0.3}}{1.966}\right)^{3.2} + 0.062\cdot\left(\dfrac{0.181^{0.3}}{1.966}\right)^{0.7} = 0.027$

$\dfrac{0.027}{0.6154} = 0.044$

Total penetration can be taken as the sum of initial penetration and penetration due to pipe movement

$$z_p = z_{pi} + z_{pm} \qquad (3.27)$$

Initial penetration on sand can be taken as:

$$\frac{z_{pi}}{D} = 0.037\cdot\kappa_s^{-0.67} \qquad (3.28)$$

Initial penetration on clay can be taken as:

$$\frac{z_{pi}}{D} = 0.0071\cdot\left(\frac{G_c^{0.3}}{\kappa_c}\right)^{3.2} + 0.062\cdot\left(\frac{G_c^{0.3}}{\kappa_c}\right)^{0.7} \qquad (3.29)$$

Maka rpeny = $1.0 - 1.4\cdot\dfrac{0.12}{0.6154} = 0.727$

rtry = $1.0 - 0.18\cdot(15-5)^{0.25}\cdot\left(\dfrac{0.918}{0.6154}\right)^{0.42} = 0.621$

This object are excusing with penetration on sand, thus we use formula 3.28

zpi= $\dfrac{0.074}{0.6514} = 0.114$

rperm= 0.7

rpernz= $1.0-1.3\cdot\left(\frac{0.12}{0.6154}-0.1\right)=0.877$

rtrz $=1.0-0.14\cdot(15-5)^{0.43}\cdot\left(\frac{0.918}{0.6154}\right)^{0.46}=0.547$

therefore, rtotalz calculation is=
$0.7\cdot0.877\cdot0.547=0.336$

and rtotaly=
$0.727\cdot0.621=0.451$

B.1.3.2. Menghitung *Passive Resistance*

Untuk mengetahui *passive resitance* pada tanah berjenis *clay,* dapat menggunakan persamaan berikut:

$$\frac{F_R}{F_C}=\frac{4{,}1\cdot k_c}{G_c^{\,0.39}}\cdot\left(\frac{z_p}{D}\right)^{1{,}31}$$

$$FR=\frac{4.1\cdot0.562}{0.181^{0.39}}\cdot\left(\frac{0.114}{0.6514}\right)^{1.31}=0.458$$

$$0.458\cdot2190=1.003\cdot10^{3}$$

FY= $0.336\cdot0.5\cdot1025\cdot0.6514\cdot6.63\cdot(0.34+0.144)^2=174.215$ N/m

FZ= $0.336\cdot0.5\cdot1025\cdot0.6514\cdot2.87\cdot(0.34+0.144)^2=75.414$ N/m

Lampiran 14. Perhitungan Stabilitas Lateral

CALCULATION OF PIPELINE LATERAL STABILITY

$$2.16\cdot\frac{174.215+0.2\cdot75.414}{0.2\cdot(2.631\cdot10^{5})+1.003\cdot10^{3}}=0.008$$

so the result are required less than <1.1
according to DNV RP-109 2017

...date static stability requirement if:

(3.38)

(3.39)

3.6.3 Safety factors

The safety factors γ_{SC} to be used for absolute stability in regular winter sea states are listed in Tables 3.5 and 3.6.

Table 3.5 Safety factors, winter storms in North Sea			
	Low	*Normal*	*High*
Sand and rock	0.98	1.32	1.67
Clay	1.00	1.40	1.83

Table 3-6 Safety factors, winter storms in Gulf of Mexico and Southern Ocean			
	Low	*Normal*	*High*
Sand and rock	0.95	1.41	1.99
Clay	0.97	1.50	2.16

If cyclonic cases are governing for on-bottom stability design, the safety factors γ_{SC} to be used for absolute stability in cyclonic conditions are listed in Tables 3.7 and 3.8.

Table 3.7 Safety factors, cyclonic conditions North West Shelf			
	Low	*Normal*	*High*
Sand and rock	0.95	1.50	2.18
Clay	0.95	1.56	2.31

Table 3-8 Safety factors, cyclonic conditions Gulf of Mexico			
	Low	*Normal*	*High*
Sand and rock	0.95	1.64	2.46
Clay	0.93	1.64	2.54

For other areas than those mentioned above, conservative assumptions should be made for the choice of safety factors.