Mooring Forces Calculator (Port or Starboard on Quay)

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What does this Excel Sheet do?

This Excel sheet helps you calculate the environmental forces on a vessel when it is moored by Port or Starboard Side aligned with the Quay (as shown in figure on right)
It further calculates the Line Tensions on the Mooring Lines, and reports the Factor of Safety for each mooring line

How to use this Excel Sheet

The user is asked for some inputs for the Vessel, Cargo and Environment and Mooring Line Configuration. ***The Input cells are highlighted in blue.***
The user has to provide all the inputs highlighted in blue. ***Please do not make any changes to the output sheets***
For some inputs, Tables and charts are required to be referred. These Tables and charts are provided alongwith for the user to enter these inputs.
Once all inputs are provided, the Environmental forces are calculated, and from these forces, the Mooring Line Tensions are calculated
The user should conduct separate checks for normal and heavy weather conditions. Factors of safety are 9.0 for normal, and 3.0 for heavy weather condition
The mooring pattern should be investigated for both ballast and fully loaded cases for each weather condition

Coordinate System and Axes (See figure on right)

The origin of coordinate system is at fwd end of the vessel longitudinally, Centreline transversely and at Mean Sea Level vertically
X-axis is positive towards aft, Y-axis is positive towards the quay, Z-axis is positive vertically upwards

Assumptions/Limitations

Mooring line arrangement should be symmetrical about the midship of the vessel
Wind and current forces are assumed to be steady state in nature. Wave force is assumed to be negligible
The line spring coefficients are constant, i.e., the Cyoung's modulus of mooring lines does not vary much with line tension forces

References

1. DDS-582-1 Calculations for Mooring Systems, Department of the Navy, Naval Sea Systems Command, Washington DC, 20362-5101

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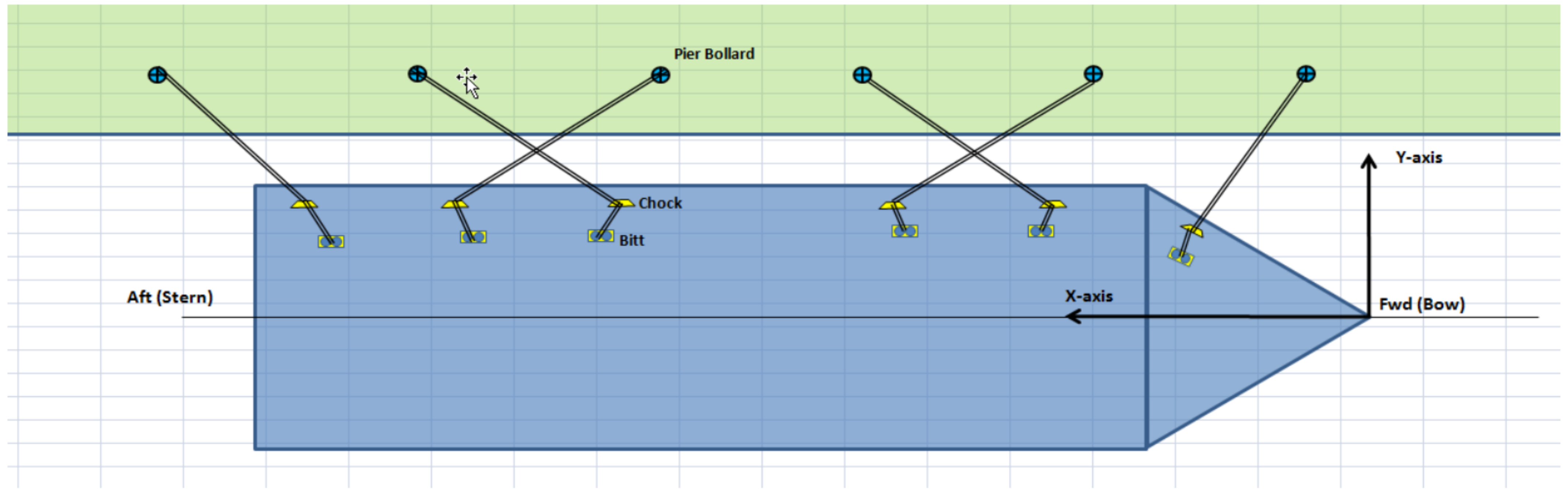

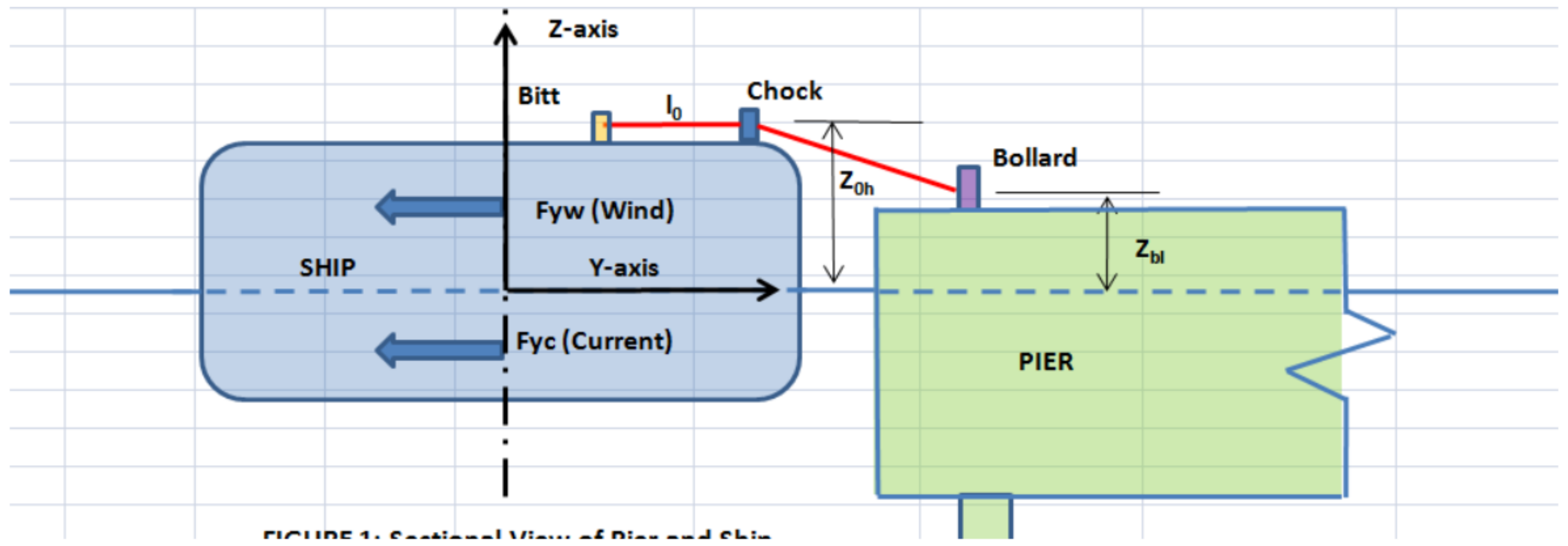

MOORING FORCES CALCULATOR (PORT/STBD ON QUAY)
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MOORING FORCES CALCULATION - VESSEL INPUTS

General Particulars				
Particular		**Value**	**Default Value**	**Units**
Acceleration due to Gravity	g	9.81	9.81	m/s^2
Density of air	ρ_{air}	1.23	1.23	kg/m^3
Density of Water	ρ_{water}	1025	1025	kg/m^3
Vessel Particulars				
Particular		**Value**		**Units**
Vessel Name		Ship 1		
Principal Particulars				
Length Waterline (LWL)	LWL	116.74		m
Breadth	B	12.53		m
Mean Draft (Working)	T	4.27		m
Ship XCG (Longitudinal CG) - from Bow	Xcg	57.91	58.37	m
Displacement	Δ	3403.75		MT
Wetted Surface Area[1]	S	1631.37	1631.37	m^2

Wind Areas				
End projected wind area[2]	A_e	0		m^2
Side projected wind Area	A_s	845.44		m^2
Vessel Type (1 - for Normal shape, 2 - for Hull Dominated shape)		1	1	

[1]The default Wetted Surface Area, S, is approximated by formula S = 2.588 * √(Displacement * LWL). User can input a different figure if available
[2]The End Projected wind Area should be input as zero if the environment is only in transverse direction

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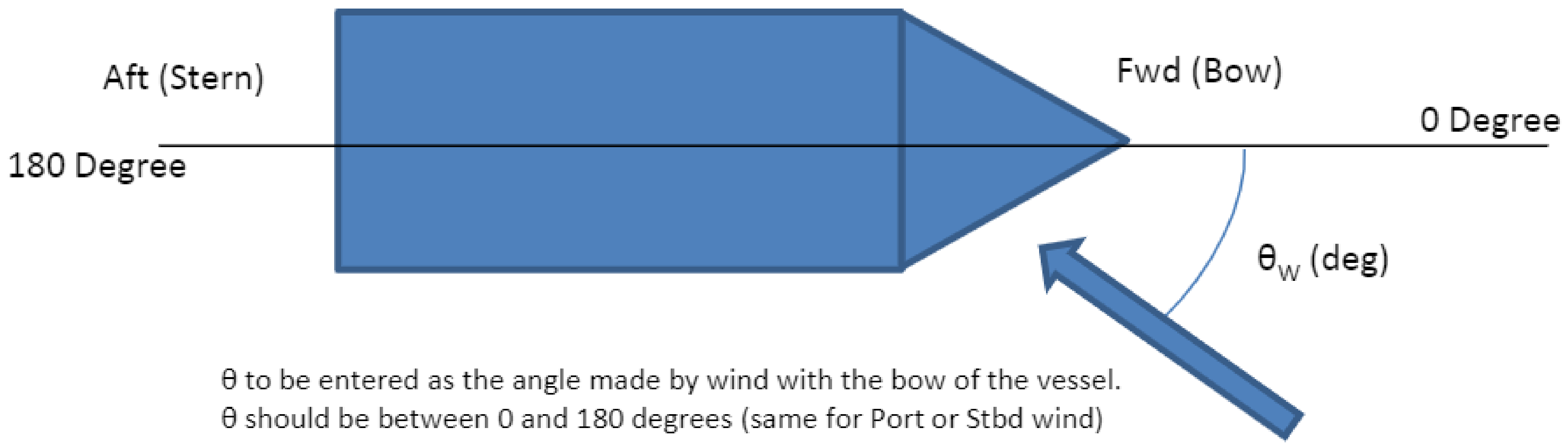
MOORING FORCES CALCULATION INPUTS- ENVIRONMENT

Wind and Current Parameters				
Particular		**Value**	**Default Value**	**Units**
Design Wind Speed	V_w	25.72	20	m/s
Wind Angle (See Fig 1) - from 0 to 180 deg	θ_w	90		degrees
Current Speed	V_c	1.5432	0.5	m/s
Current Angle (See Fig 2) - from 0 to 180 deg	θ_c	0		degrees
Water Depth	WD	13.72		m

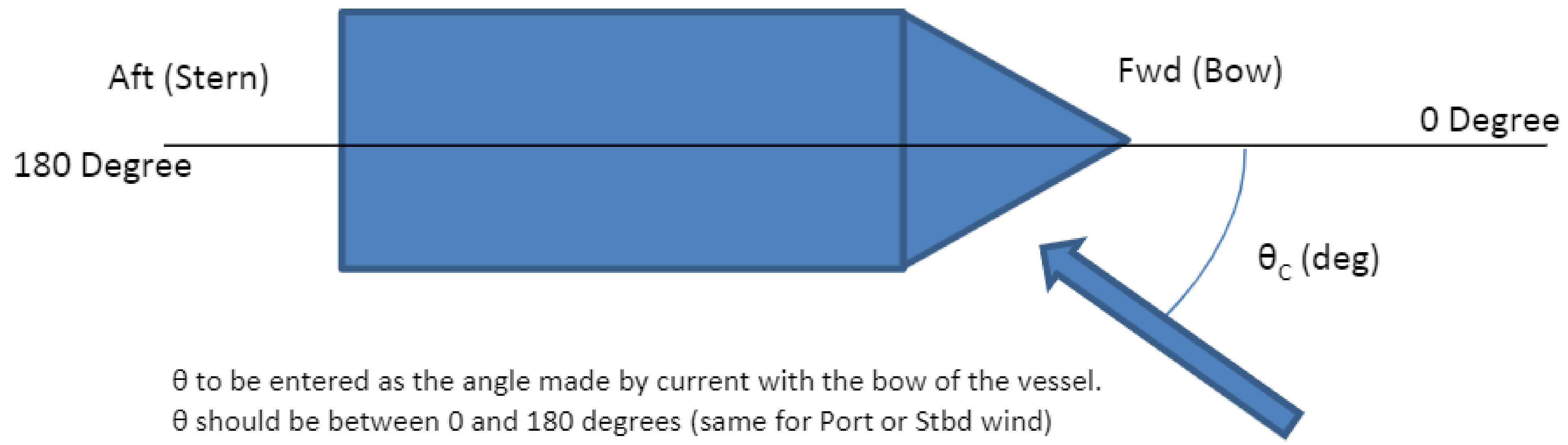
Wind at angle θ_w



θ to be entered as the angle made by wind with the bow of the vessel.
θ should be between 0 and 180 degrees (same for Port or Stbd wind)

Fig 1: Wind Angle

Current at angle θ_c



θ to be entered as the angle made by current with the bow of the vessel.
θ should be between 0 and 180 degrees (same for Port or Stbd wind)

Fig 1: Current Angle

MOORING FORCES CALCULATION INPUTS- MOORING LINES

Please input the mooring line properties in this worksheet. The maximum number of mooring lines possible is 16. The mooring pattern should be symmetrical about the vessel's midship

Line No.	Chock Coordinates on Ship (m) (See Figs 1 & 2)			Bollard Coordinates at pier (m) (See Figs 1 & 2)			Line Length from Bitt to Chock (m) (See Fig 2)	Young's modulus of rope (GPa)	No. of rope parts	Cross Sectional Area of ***one*** rope (mm^2)	Minimum breaking Strength of ***one*** rope (MT)
	X_{ch}	Y_{ch}	Z_{ch}	X_{bl}	Y_{bl}	Z_{bl}	l_o	E	n	a	MBS_{rope}
1	0	0	6.4	-7.32	8.23	2.74	3.66	1.378	3	1291	33.3
2	4.88	1.52	5.79	0	8.23	2.74	2.44	1.378	3	1291	33.3
3	11.58	2.74	5.49	21.95	8.23	2.74	2.44	1.378	3	1291	33.3
4	21.34	4.88	4.72	7.32	8.23	2.74	2.44	1.378	3	1291	33.3
5	96.93	6.1	2.9	102.41	8.23	2.74	3.05	1.378	3	1291	33.3
6	106.68	5.33	3.05	95.1	8.23	2.74	2.44	1.378	3	1291	33.3
7	110.95	4.88	3.2	117.04	8.23	2.74	2.44	1.378	3	1291	33.3
8	118.87	3.05	3.2	124.36	8.23	2.74	3.35	1.378	3	1291	33.3
9	80.47	6.1	2.9	87.78	8.23	2.74	2.44	1.378	3	1291	33.3
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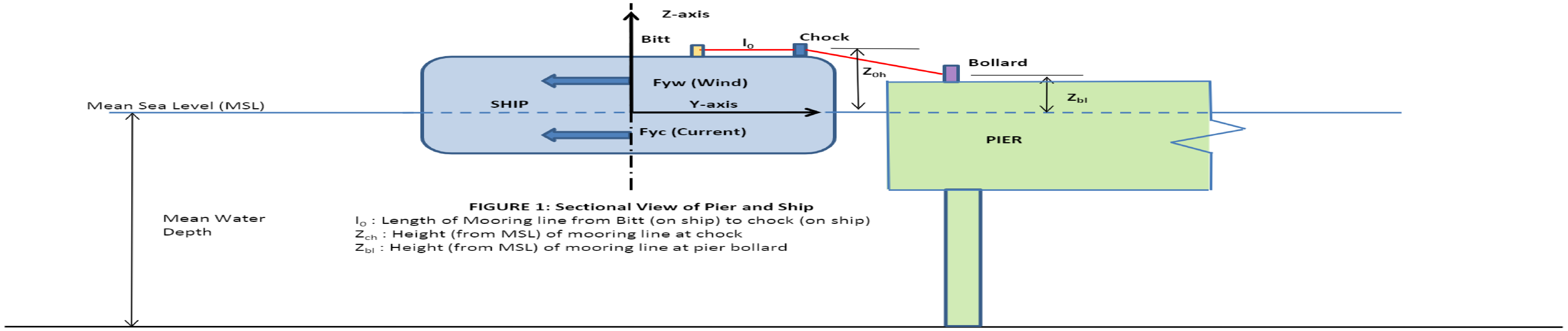


FIGURE 1: Sectional View of Pier and Ship

l_o : Length of Mooring line from Bitt (on ship) to chock (on ship)
Z_{ch} : Height (from MSL) of mooring line at chock
Z_{bl} : Height (from MSL) of mooring line at pier bollard

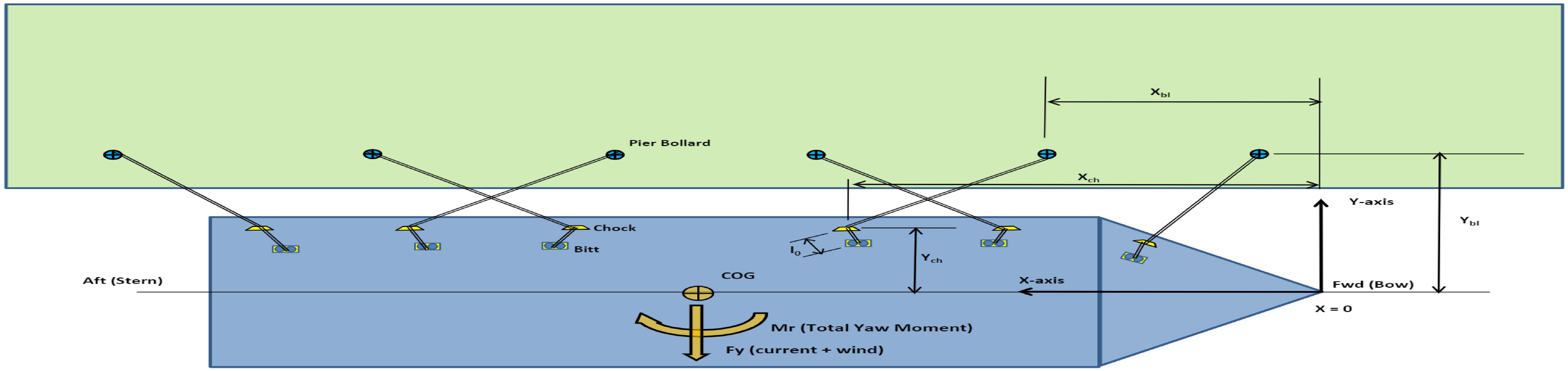


Fig 2: Plan View of a Typical Mooring Pattern
(for reference only, not reflective of actual mooring pattern entered by user)

X_{ch} : Longitudinal distance of mooring line chock from vessel's bow
Y_{ch} : Transverse distance of mooring line chock from vessel'' Centerline

Wind Forces and Yaw Moment Calculation*

* *References:*

1. DDS 582-1 Calculations for Mooring Systems, DDS-582-1-d(1)

Windload is given by:

$F_{YW} = 1/2 * C_{YW}\, \rho_{air} * V_W^2 * A_S$ (Wind Force in Transverse direction)

$F_{XYW} = 1/2 * C_{XYW}\, \rho_{air} * V_W^2 * A_S * LWL$ (Wind Yaw Moment)

ρ_{air} = Density of Air, V_w = Wind Speed , A_E = End projected Wind Ares, A_S = Side Projected Wind Area

C_{xw} = Longitudinal Wind Force Coefficient (See Table 1), C_{yw} = Lateral Wind Force Coefficient (See Table 2), C_{xyw} = Wind Yaw Moment Coefficient (See Table 3)

Basic Parameters			
Particulars	*Notation*	*Value*	*Units*
HULL			
Length of Waterline	LWL	116.74	m
End projected wind area	A_e	0	m^2
Side projected Wind Area	A_s	845.44	m^2
Design Wind Speed	V_w	25.72	m/s
Density of air	ρ_{air}	1.23	kg/m^3
Wind Angle	θ_w	90	degrees
Ship Type (1 - Normal, 2 - Hull dominated)		1	
Wind Force Coefficients			
Longitudinal Wind Force Coefficient	C_{XW}	0	See Table 1
Lateral Wind Force Coefficient	C_{YW}	1	See Table 2
Wind Yaw Moment Coefficient	C_{XYW}	-0.037	See Table 3

WINDLOAD			
Longitudinal Wind Force	**$F_{XW} = 1/2 * C_{xw} * \rho_{air} * V_w^2 * A_E$**	**0.00**	MT
Lateral Wind Force	**$F_{YW} = 1/2 * C_{yw} * \rho_{air} * V_w^2 * A_S$**	**35.06**	MT
Total Factored Windage Area of Hull in Lateral Direction	**$M_W = 1/2 * C_{xyw} * \rho_{air} * V_w^2 * A_S * LWL$**	**-151.44**	MT-m

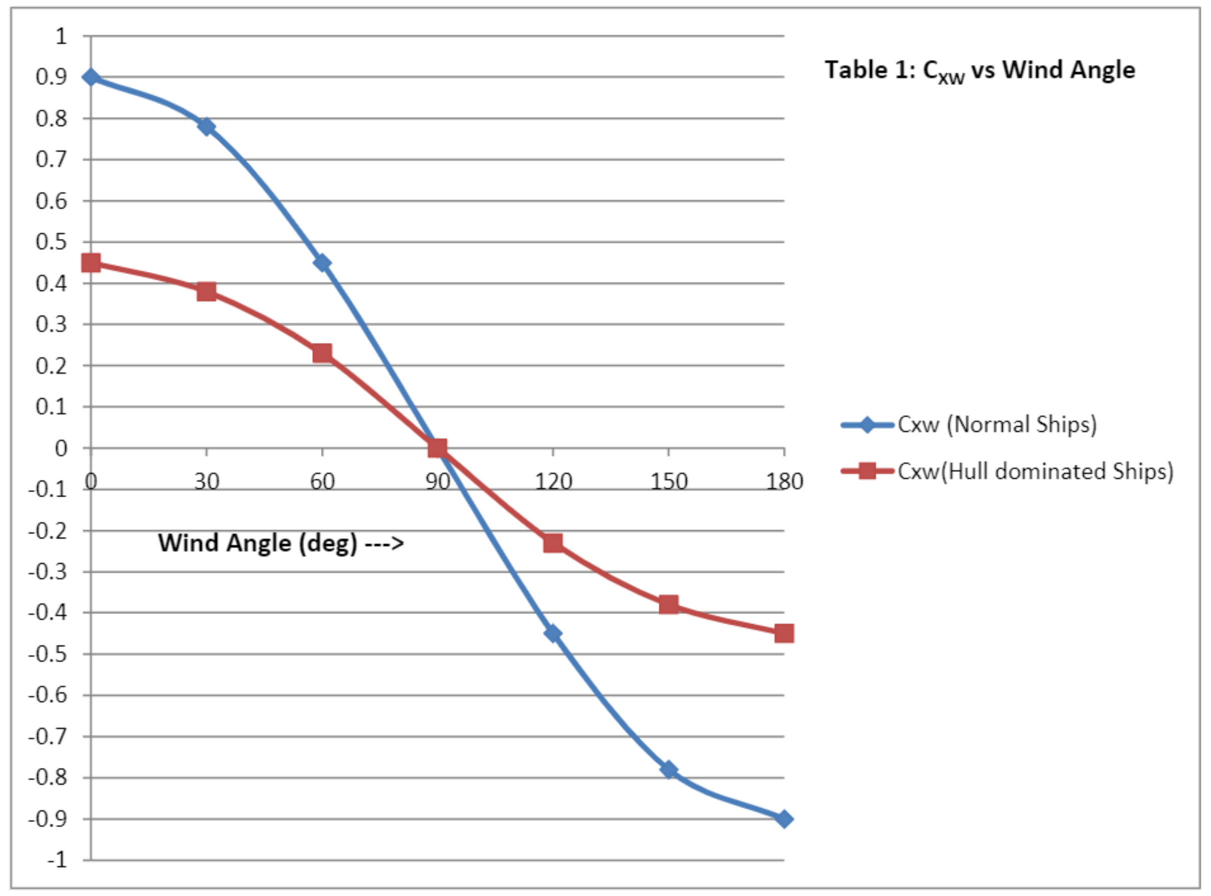


Table 1: C_{XW} vs Wind Angle

C_{XW}		
Angle (deg)	Cnormal	Chull
0	0.9	0.45
30	0.78	0.38
60	0.45	0.23
90	0	0
120	-0.45	-0.23
150	-0.78	-0.38
180	-0.9	-0.45

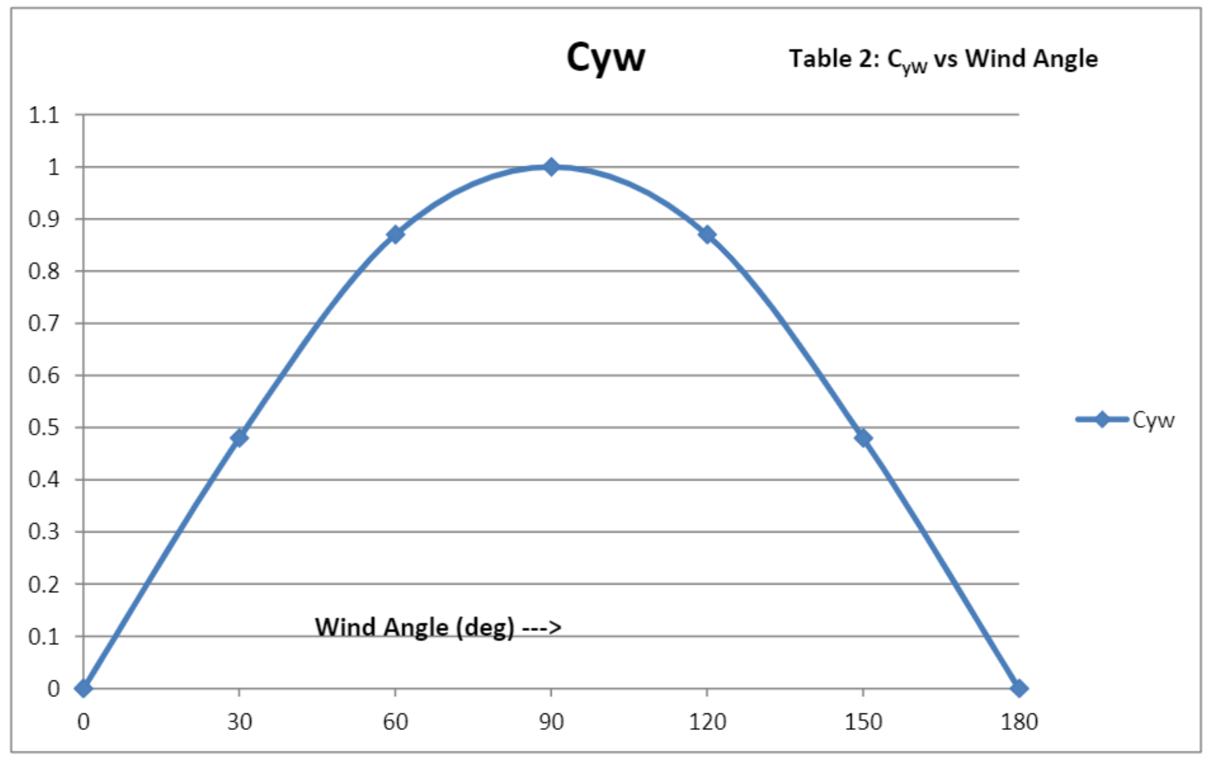


Table 2: C_{yw} vs Wind Angle

C_{YW}	
Angle (deg)	C_{YW}
0	0
30	0.48
60	0.87
90	1
120	0.87
150	0.48
180	0

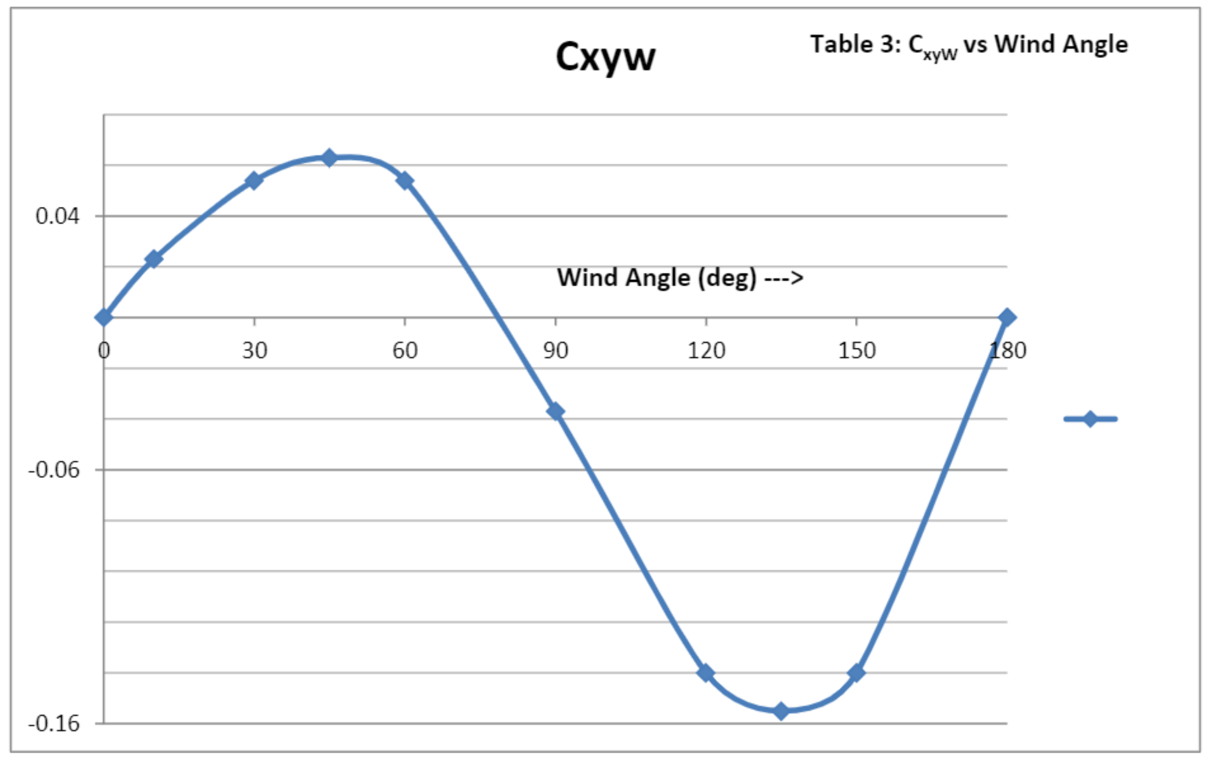


Table 3: C_{xyw} vs Wind Angle

C_{XYW}	
Angle (deg)	C_{XYW}
0	0
10	0.023
30	0.054
45	0.063
60	0.054
90	-0.037
120	-0.14
135	-0.155
150	-0.14
180	0

Current Forces and Yaw Moment Calculation*

* *References:*

1. *DDS 582-1 Calculations for Mooring Systems, DDS-582-1-d(2)*

Current Forces and Moments are given by:

F_{YC} = 1/2 * C_{YC} ρ_{water} * V_C^2 * LWL * T (Current Force in Transverse direction)

F_{XYC} = 1/2 * C_{XYC} ρ_{air} * V_C^2 * LWL^2 * T (Current Yaw Moment)

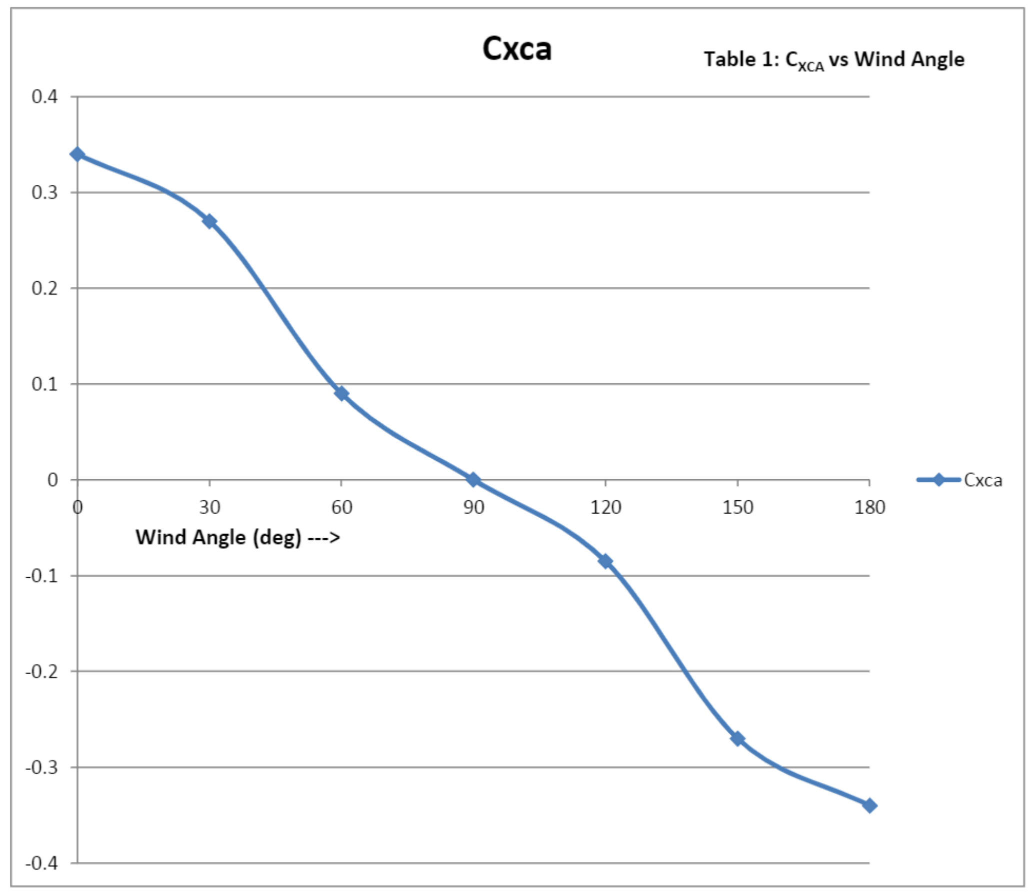
ρ_{water} = Density of Water, V_C = Current Speed, C_{XCA} = Longitudinal Current Skin Friction Coefficient (Table 1), C_{XCB} = Longitudinal Current Drag Coefficient

C_{YC} = Lateral Current Force Coefficient (See Table 2), C_{XYC} = Current Yaw Moment Coefficient (See Table 3), S = Wetted Surface Area of Hull

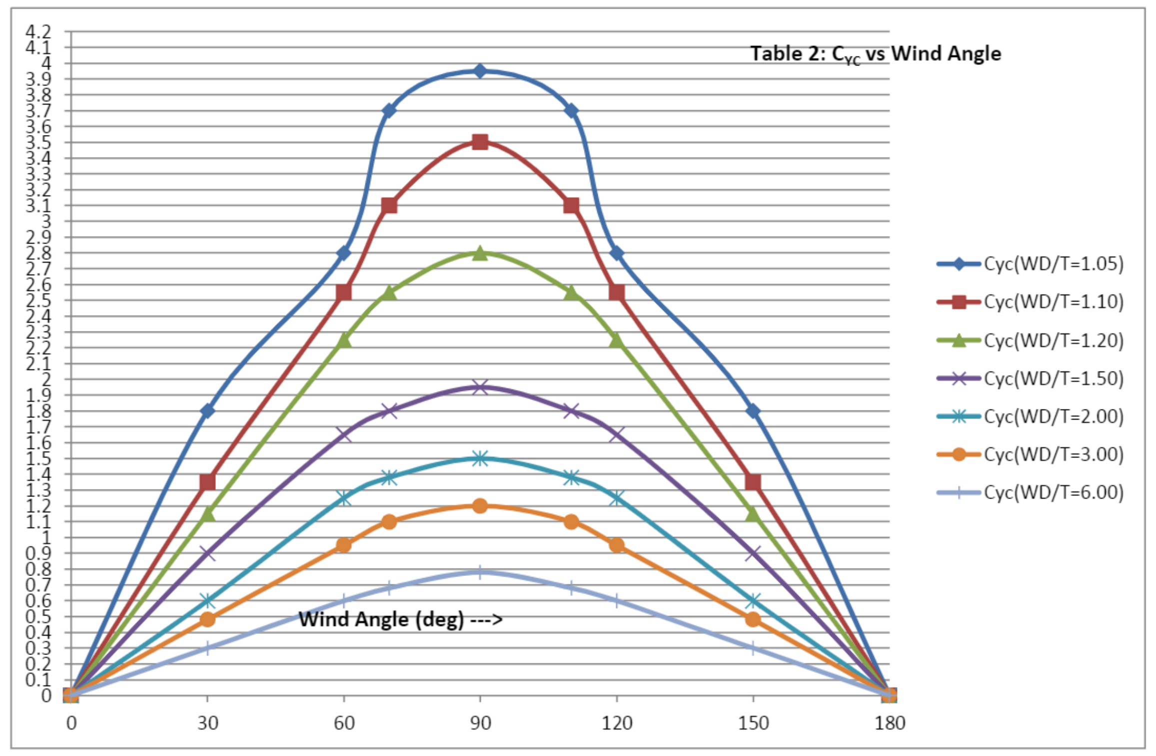
Note 1: C_{XCB} is given by formula C_{XCB} = C_{YC} * $\cos^2\theta_C$

Basic Parameters			
Particulars	*Notation*	*Value*	*Units*
HULL			
Length of Waterline	LWL	116.74	m
Breadth	B	12.53	m
Draft	T	4.27	m
Water Depth	WD	13.72	m
Wetted Surface Area	S	1631.37	m^2
Design Current Speed	V_C	1.5432	m/s
Density of water	ρ_{water}	1025	kg/m^3
Current Angle	θ_C	0	degrees
Ratio of Water Depth to Draft WD/T	WD/T	3.22	
Current Force Coefficients			
Longitudinal Current Skin Friction Coefficient	C_{XCA}	0.3400	See Table 1
Lateral Current Force Coefficient	C_{YC}	0.0000	See Table 2
Longitudinal Current Drag Coefficient	C_{XCB}	0.0000	C_{YC} * $\cos^2\theta_C$
Current Yaw Moment Coefficient	C_{XYC}	0.0000	See Table 3

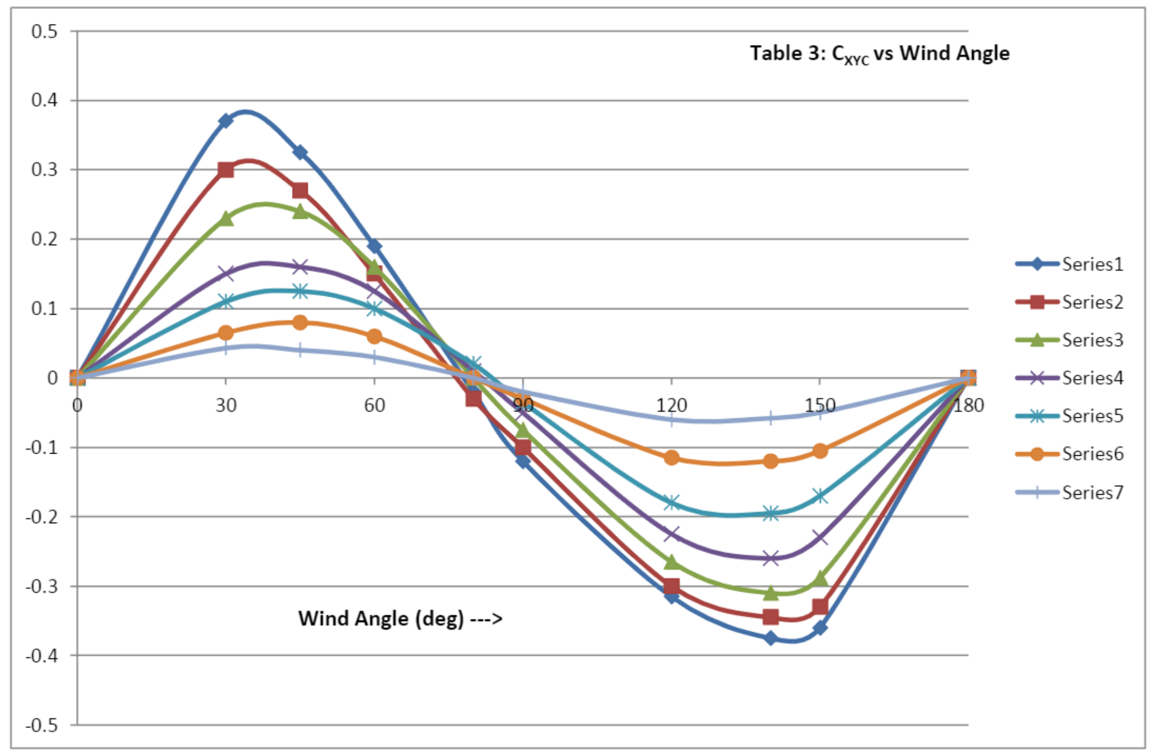
WINDLOAD			
Longitudinal Current Force	**F_{XC} = 1/2 * ρ_{water} * V_C^2 * B * (C_{XCA} * S/LWL + C_{XCB} * T)**	**7.41**	MT
Lateral Current Force	**F_{YC} = 1/2 * C_{YC} * ρ_{water} * V_C^2 * LWL * T)**	**0.00**	MT
Current Yaw Moment	**F_{XYC} = 1/2 * C_{XYC} * ρ_{water} * V_C^2 * LWL^2 * T)**	**0.00**	MT-m



C_{XCA}	
Angle (deg)	C_{xca}
0	0.34
30	0.27
60	0.09
90	0
120	-0.085
150	-0.27
180	-0.34



C_{YC}							
Angle (deg)	WD/T = 1.05	WD/T = 1.10	WD/T = 1.20	WD/T = 1.50	WD/T = 2.00	WD/T = 3.00	WD/T = 6.00
0	0	0	0	0	0	0	0
30	1.8	1.35	1.15	0.9	0.6	0.48	0.3
60	2.8	2.55	2.25	1.65	1.25	0.95	0.6
70	3.7	3.1	2.55	1.8	1.38	1.1	0.68
90	3.95	3.5	2.8	1.95	1.5	1.2	0.78
110	3.7	3.1	2.55	1.8	1.38	1.1	0.68
120	2.8	2.55	2.25	1.65	1.25	0.95	0.6
150	1.8	1.35	1.15	0.9	0.6	0.48	0.3
180	0	0	0	0	0	0	0



C_{XYC}							
Angle (deg)	WD/T = 1.05	WD/T = 1.10	WD/T = 1.20	WD/T = 1.50	WD/T = 2.00	WD/T = 3.00	WD/T = 6.00
0	0	0	0	0	0	0	0
30	0.37	0.3	0.23	0.15	0.11	0.065	0.043
45	0.325	0.27	0.24	0.16	0.125	0.08	0.04
60	0.19	0.15	0.16	0.125	0.1	0.06	0.03
80	-0.02	-0.03	0	0.01	0.02	0	0
90	-0.12	-0.1	-0.075	-0.05	-0.035	-0.03	-0.02
120	-0.315	-0.3	-0.265	-0.225	-0.18	-0.115	-0.06
140	-0.375	-0.345	-0.31	-0.26	-0.195	-0.12	-0.058
150	-0.36	-0.33	-0.288	-0.23	-0.17	-0.105	-0.05
180	0	0	0	0	0	0	0

Final Total Forces and Moment

* *References:*

1. *DDS 582-1 Calculations for Mooring Systems, DDS-582-1-d(3)*

FINAL FORCES AND MOMENTS			
Longitudinal Wind + Current Force	$F_X = F_{XC} + F_{XW}$	**7.41**	MT
Lateral Wind + Current Force	$F_Y = F_{YC} + F_{YW}$	**35.06**	MT
Total Yaw Moment	$M_r = M_C + M_W - 0.48 * LWL * F_X$	**-566.40**	MT-m

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MOORING FORCES CALCULATION - MOORING LINE FORCES

* *References:*

1. DDS 582-1 Calculations for Mooring Systems, DDS-582-1-e

*Note: Factor of Safety should be more than 9 for Normal environment, and more than 3 for extreme environment

F_Y (kN)	343.95	a (kN/m)	1910.042	δ_y (m) =	0.266
M_r (kN-m)	-5556.40	b (kN)	117866.463	$\delta_y = (F_y{*}c - (M_r + F_y{*}X_{cg}){*}b)/(ac-b^2)$	
X_{cg}(m)	57.91	c (kN-m)	12175733.665	γ (radian)	-0.001399758
				$\gamma = (F_y{*}b - (M_r + F_y{*}X_{cg}){*}a)/(b^2-ac)$	

Line No.	Chock Coordinates on Ship (m) See Fig 1 & Fig 2			Bollard Coordinates at pier (m) See Fig 1 & Fig 2			$l_1 = \sqrt{(X_{ch} - X_{bl})^2 + (Y_{ch} - Y_{bl})^2}$ See Fig 2	$\Delta Z_i = Z_{ch} - Z_{bl}$ See Fig 1	Cross Sectional Area of one rope (mm^2)	No. of rope parts	Cross Sectional Area of mooring line (mm^2)	Minimum breaking Strength of one rope (MT)	Minimum breaking Strength of Mooring Line (MT)
	X_{ch}	Y_{ch}	Z_{ch}	X_{bl}	Y_{bl}	Z_{bl}	l_1	ΔZ_i	a	n	$a_i = n \times a$	MBS_{rope}	$MBS = MBS_{rope} \times n$
1	0	0	6.4	-7.32	8.23	2.74	11.01	3.66	1291	3	3873	33.3	99.9
2	4.88	1.52	5.79	0	8.23	2.74	8.3	3.05	1291	3	3873	33.3	99.9
3	11.58	2.74	5.49	21.95	8.23	2.74	11.73	2.75	1291	3	3873	33.3	99.9
4	21.34	4.88	4.72	7.32	8.23	2.74	14.41	1.98	1291	3	3873	33.3	99.9
5	96.93	6.1	2.9	102.41	8.23	2.74	5.88	0.16	1291	3	3873	33.3	99.9
6	106.68	5.33	3.05	95.1	8.23	2.74	11.94	0.31	1291	3	3873	33.3	99.9
7	110.95	4.88	3.2	117.04	8.23	2.74	6.95	0.46	1291	3	3873	33.3	99.9
8	118.87	3.05	3.2	124.36	8.23	2.74	7.55	0.46	1291	3	3873	33.3	99.9
9	80.47	6.1	2.9	87.78	8.23	2.74	7.61	0.16	1291	3	3873	33.3	99.9
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Line No.	Young's modulus of rope (GPa)	$\cos\theta_i = (Y_{bl} - Y_{ch})/l_1$ See Fig 2	$\phi_i = \tan^{-1}(\Delta Z_i/l_1)$ See Fig 1	$\cos\phi_i$	Line Length from Bitt to Chock (m) See Fig 2	$L_i = l_0 + l_1/\cos\phi_i$ (m)	$k_i = a_i * E_i/L_i$ (kN/m)	$k_{yi} = k_i * \cos\theta_i * \cos\phi_i$ (kN/m)	$k_{yi} * X_{ch}$ (kN)	$k_{yi} * X_{ch}^2$ (kN-m)	$F_{yi} = k_{yi} * (\delta_y + X_{ch} * \gamma)$ (MT)	$T_i = F_{yi}/(\cos\theta_i * \cos\phi_i)$ (MT)	FS_i (Factor of Safety) = MBS/T_i
	E_i	$\cos\theta_i$	ϕ_i	$\cos\phi_i$	l_0	L_i	k_i	k_{yi}	$k_{yi} * X_{ch}$	$k_{yi} * X_{ch}^2$	F_{yi}	T_i	FS_i
1	1.378	0.748	18.388	0.94894	3.66	15.262	349.682	248.042	0.000	0.000	6.737	9.498	10.518
2	1.378	0.808	20.177	0.93863	2.44	11.283	473.027	358.943	1751.642	8548.012	9.499	12.519	7.980
3	1.378	0.468	13.194	0.97360	2.44	14.488	368.372	167.858	1943.798	22509.185	4.282	9.397	10.631
4	1.378	0.232	7.824	0.99069	2.44	16.985	314.211	72.367	1544.311	32955.599	1.745	7.578	13.183
5	1.378	0.362	1.559	0.99963	3.05	8.932	597.502	216.362	20971.968	2032812.860	2.884	7.965	12.542
6	1.378	0.243	1.487	0.99966	2.44	14.384	371.036	90.087	9610.515	1025249.783	1.076	4.430	22.551
7	1.378	0.482	3.787	0.99782	2.44	9.405	567.451	272.922	30280.742	3359648.291	3.092	6.429	15.538
8	1.378	0.686	3.487	0.99815	3.35	10.914	489.004	334.881	39807.348	4731899.415	3.416	4.988	20.028
9	1.378	0.280	1.204	0.99978	2.44	10.052	530.955	148.579	11956.139	962110.519	2.330	8.325	12.000
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								a = 1178.54	b = 66102.98	c = 6481723.73			

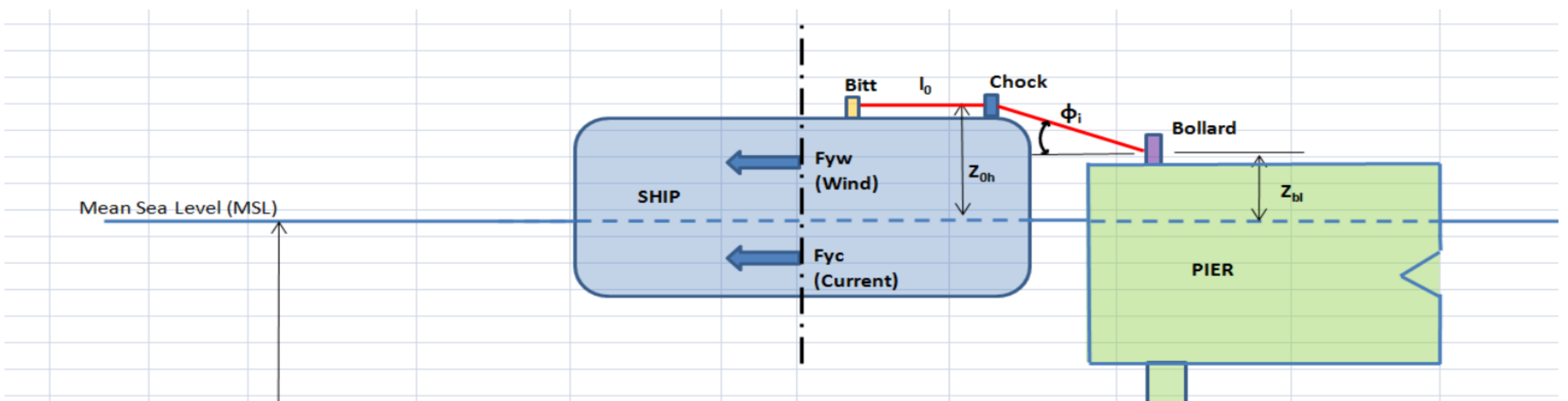

FIGURE 1: Sectional View of Pier and Ship

l_0 : Length of Mooring line from Bitt (on ship) to chock (on ship)

Z_{ch} : Height (from MSL) of mooring line at chock

Z_{bl} : Height (from MSL) of mooring line at pier bollard

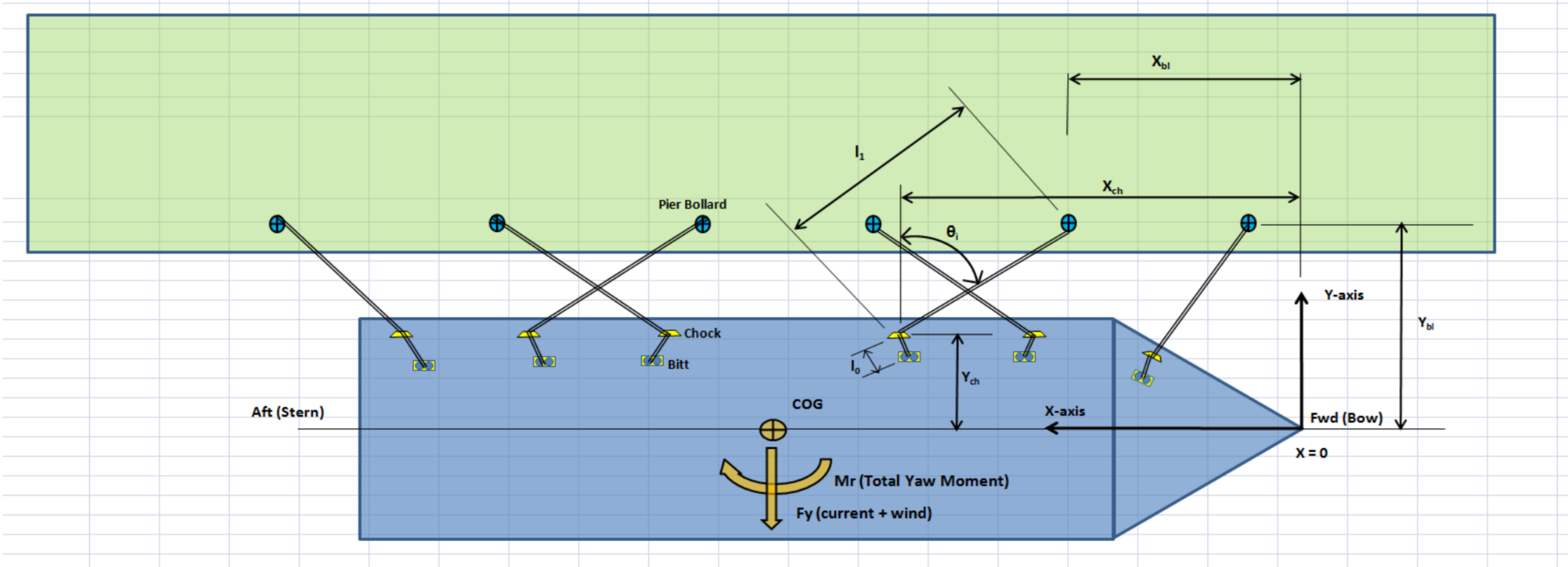

Fig 2: Plan View of a Typical Mooring Pattern
(for reference only, not reflective of actual mooring pattern entered by user)

X_{ch} : Longitudinal distance of mooring line chock from vessel's bow

Y_{ch} : Transverse distance of mooring line chock from vessel" Centerline

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