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Strength Analysis of the Floating Pier Structure with Passenger Ship 116 GT (Case Study: Sanur Harbor, Bali Province)

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ABSTRACT

The pier is one of the primary means of sea transportation that continues to be developed to support equity activities and advance the community's economy. Bali is one of the main tourist destinations in Indonesia. The construction of the Sanur Floating Pier will create good connectivity between regions in Bali, which can become an additional tourist destination so that tourists can vacation longer in Bali. The purpose of this study was to determine the strength of the floating jetty structure through an analysis of the loading received by the structure and the resistance of the piles so that they can carry out designs related to the installation of strong and safe floating dock piles. In the analysis process, the author uses the help of Plaxis V.8.6 software to model the soil and AutoCAD 2018 as a support system in making the floating dock pile installation layout. The analysis results show that the floating dock can accept the forces acting on the structure. The UE RPD 250 fender and the T-Head MT 20 type bollard are the right choices. The pile has a lateral force value (H) of 1907 kg with a deflection of 0.19 mm. The greater the number of piles installed on the floating pier, the stronger the structure is evidenced by the smaller pile settlement due to soil changes.

Keywords: *bollard, deflection, fender, floating jetty, pile.*

1. INTRODUCTION

Regional development is an effort to change the current conditions into a new, better conditions for the greater prosperity of the people in the area. For this reason, it is necessary to develop adequate facilities and infrastructure to support economic progress. Indonesia is an archipelagic/maritime country, and shipping is crucial for social life, economy, government, and defense/security (Bambang Triatmodjo, 2010).

In order to support economic progress in the Bali region, the Ministry of Transportation of the Republic of Indonesia is currently developing the Sanur Port. The port of Sanur, currently under construction, will connect areas known as the golden triangle, namely Sanur, Nusa Penida, and Nusa Ceningan. The groundbreaking was carried out by the Minister of Transportation of the Republic of Indonesia, Budi Karya Sumadi, at Matahari Terbit Beach, Sanur Kaja Village, South Denpasar District, Denpasar City, Bali Province. Bali is a major tourist destination. The presence of Sanur Port will create good connectivity between areas in Bali (Sanur-Nusa Penida-Nusa Ceningan), which can be an additional tourist destination so that tourists can vacation longer in Bali.

Figure 1. Condition of Sanur Port (Source: Master Plan for Sanur Port, Denpasar City, Bali Province, Ministry of Transportation 2019)

2. METHODOLOGY

The research procedures in this study are:

2.1 Study of Literature

The literature study was conducted to find, study, and understand basic theories, literature reviews, journals, and books related to the final project. Plaxis V.8.6 and AutoCAD software were used to support this study.

2.2 Data Collection

1. Wind Data

This analysis's wind data is derived from observations of the BMKG Ngurah Rai station in 2011-2020 (10 years).

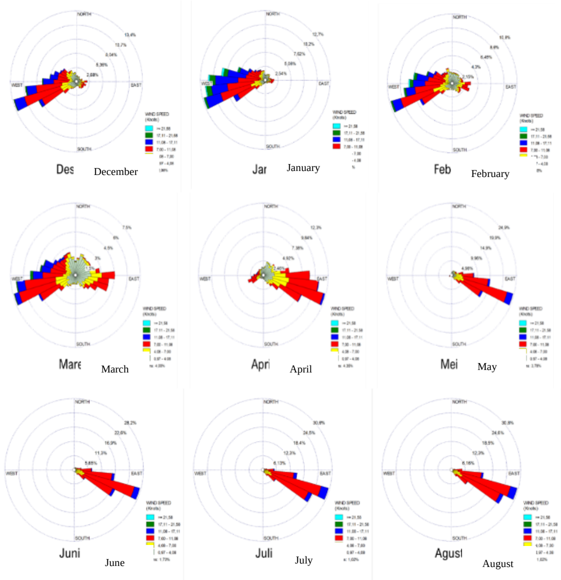


Figure 2. Wind Rose Data

2. Current Data
Measure the tidal currents with the Acoustic Doppler Current Profiler (ADCP) type Argonaut XR 200 at positions 309013.87 E and 9041508.53 S.

Figure 3. Field Survey Location

The results of plotting the current rose for the average of all cells (all depths) are as follows:

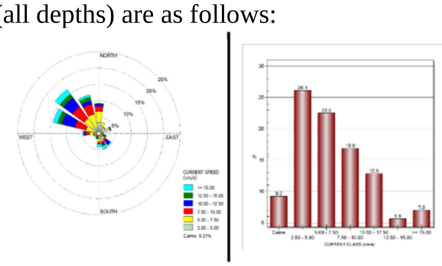
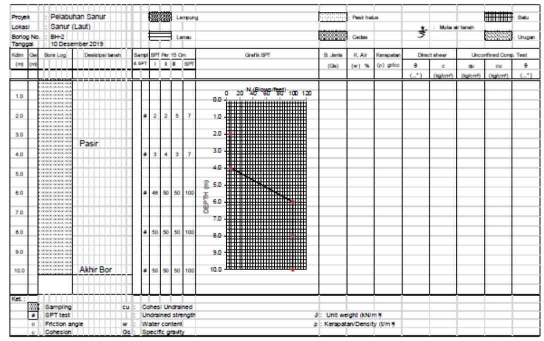


Figure 4. Current Rose (Left) and Current Velocity Graph (Right) in Sanur Beach.

3. Land Data
Based on the Master Plan for Sanur Port, Denpasar City, Bali Province, the Ministry of Transportation 2019, two points have been drilled, namely the BH-1 point on land and the BH-2 point at sea to produce soil test data (Geotechnical). Because this research focuses on planning a floating jetty to be built on the sea, the data processed is Bore Log data at Sea (BH-2).

Table 1. Bore Log Data at Sea (BH-2)



2.3 Modeling
1. Dock Modeling

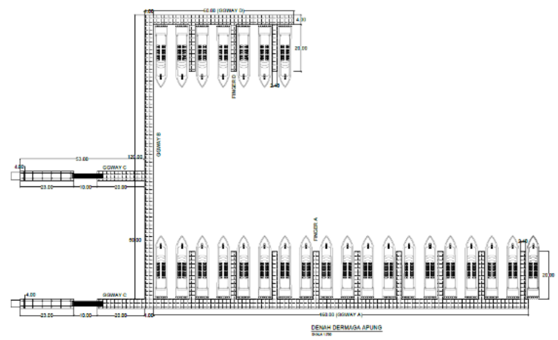


Figure 5.Sanur Floating Dock Layout

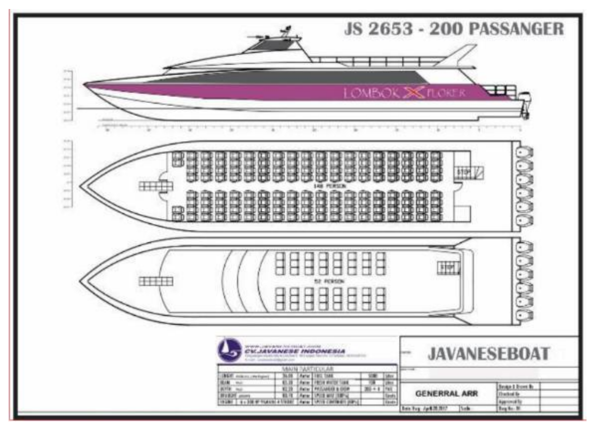


Figure 6. Ship specification design

Planned Ship Specifications:
Ship Type : Passenger Ship
Capacity : 200 people
Gross Tonnage : 116 GT
Length (LoA) : 26 m
Width (B) : 5.3 m
Draft : 1 m

Tidal elevation at the site:
High Water Spring, HWS: + 2,597 mLWS
Lowest Water Spring, LWS: ± 0.00 mLWS

2. Land Modeling
Soil modeling was carried out using Plaxis V.8.6 software to determine the soil changes that occurred (deformed mesh).

2.4 Analysis and Discussion
Determine the loading that occurs on the floating dock, determine fenders and bollards, analyze Broms lateral bearing capacity, analyze pile deflection, and analyze pile settlement using Plaxis V.8.6 software based on variations in Pile Installation Layout that has been made with the software AutoCAD 2018.

2.5 Conclusions
Conclusions are drawn that can answer the formulation of the problem from this research.

3. RESULTS AND DISCUSSIONS

3.1 Loading

3.1.1 Vertical Loading

In this study, because the pier is a floating pier, the vertical motion or loading is freed (zero) because vertical loads such as live loads and dead loads are not supported by piles but are supported by water. Piles only get lateral loads.

3.1.2 Horizontal Loading

1. Berthing
a) Determining Displacement tonnage (Ms)

Table 2. Determination of Ship Tonnage Displacement

Cargo ships (10,000*DWT* or more) :	log (*DT*) = 0.511 + 0.913 log (*DWT*)
Container ships :	log (*DT*) = 0.365 + 0.953 log (*DWT*)
Ferries (long distance) :	log (*DT*) = 1.388 + 0.683 log (*GT*)
Ferries (short-to-medium distance) :	log (*DT*) = 0.506 + 0.904 log (*GT*)
Roll-on/roll-off vessels :	log (*DT*) = 0.657 + 0.909 log (*DWT*)
Passenger ships (Japanese) :	log (*DT*) = 0.026 + 0.981 log (*GT*)
Passenger ships (foreign) :	log (*DT*) = 0.341 + 0.891 log (*GT*)
Car carriers :	log (*DT*) = 1.915 + 0.588 log (*GT*)
Oil tankers :	log (*DT*) = 0.332 + 0.956 log (*DWT*)

Passenger ships (foreign) :
Log (DT) = 0,341 + 0,891 log (GT)
= 0,341 + 0,891 log (116)
= 2,18
DT = 151,36 ton

b) Determine the speed of the mooring ship (v)

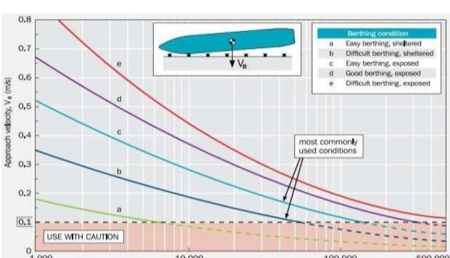


Figure 7. The speed of mooring ship graph

Table 3. Determination of the speed of mooring ship

DWT	Velocity (m/s)				
	a	b	c	d	e
1,000	0.179	0.343	0.517	0.669	0.865
2,000	0.151	0.296	0.445	0.577	0.726
3,000	0.136	0.269	0.404	0.524	0.649
4,000	0.125	0.25	0.387	0.487	0.597
5,000	0.117	0.236	0.352	0.459	0.558
10,000	0.094	0.192	0.287	0.377	0.448
20,000	0.074	0.153	0.228	0.303	0.355
30,000	0.064	0.133	0.198	0.264	0.309
40,000	0.057	0.119	0.178	0.239	0.279
50,000	0.052	0.11	0.164	0.221	0.258
100,000	0.039	0.083	0.126	0.17	0.2
200,000	0.028	0.062	0.095	0.131	0.158
300,000	0.022	0.052	0.08	0.113	0.137
400,000	0.019	0.045	0.071	0.099	0.124
500,000	0.017	0.041	0.064	0.09	0.115

From the figures and tables, the value of the speed of the mooring vessel can be obtained by:

v = 0.179 m/s.

c) Determining Virtual Mass Factor (C_M)
In determining the CM, the standard rules of PIANC (2002) are used, namely by comparing the value of Kc, namely the depth from the bottom of the ship with maximum draft conditions (D):

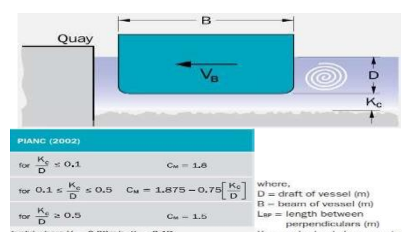


Figure 8. CM Coefficient Calculation

Then the value of the CM coefficient is obtained by:

$$\frac{Kc}{D} = \frac{1}{1} = 1$$

So based on Figure 3.2, the calculation of the CM coefficient is as follows:

$C_M = 1,5$

d) Determining Eccentricity Factor (C_E)
In determining the coefficient of eccentricity or C_E, the assumption approach of the ship hitting the fender at the berthing time. There are three possible conditions when the ship docks, namely a quarter of the ship hitting the fender (Quarter-point berthing), a third of the ship hitting the fender (third-point berthing), and half of the ship hitting the fender (mid-point berthing).

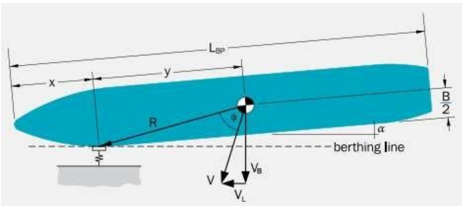


Figure 9. Determination of C_E Coefficient

In this case, it is determined based on the general case of the continuous berth with the initial assumption that the ship is moored at a position of one-third of the LoA (Third-point berthing). So with this assumption, the C_E value can be determined as 0.8.

e) Determining Cushion Coefficient (Cc)
The coefficient Cc is chosen based on the type of construction used in the planned structure. Both are open, closed, or semi-open types of structures. The determination of the Cc coefficient can be seen in Figure 4.4. In addition to calculating the effect of bearings on the condition of the open pier structure, the value of Cc = 1.

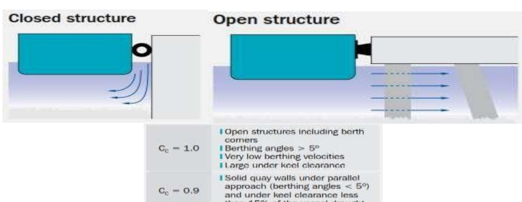


Figure 10. Determination of Cc

f) Determining Softness Coefficient (Cs)
The coefficient Cs is determined to anticipate the effect of elastic deformation on the ship's condition and mooring construction which can be seen in Figure 3.5. It is assumed that there is no deformation, therefore the value of Cs = 1

$C_S = 1.0$	Soft fenders ($\delta_f > 150$mm)
$C_S = 0.9$	Hard fenders ($\delta_f \leq 150$mm)

Figure 11. Determination of Cs

g) Determining Normal Kinetic Energy
Determine the Normal Kinetic Energy, used following calculations are carried out:

$$Ef = (\tfrac{1}{2} \times Ms \times V^2) \times C_M \times C_E \times Cc \times Cs$$

$$Ef = (\tfrac{1}{2} \times 151{,}36 \times 0{,}179^2) \times 1{,}5 \times 0{,}8 \times 1 \times 1$$
$$Ef = 2{,}91 \text{ kNm}$$

h) Determining Abnormal Kinetic Energy
Determine the kinetic energy of ships moored in abnormal conditions using the following calculations are carried out:

$$E_A = Fs \times Ef$$

Information :
Fs = Safety factor
Ef = Kinetic energy of the normal collision

Table 4. Abnormal moored ship safety factor

VESSEL TYPE	SIZE	F_S
Tanker, bulk, cargo	Largest Smallest	1.25 1.75
Container	Largest Smallest	1.5 2.0
General cargo	–	1.75
RoRo, ferries	–	≥ 2.0
Tugs, workboats, etc	–	2.0

Source: PIANC 2002; Table 4.2.5.

$$E_A = Fs \times Ef = 2 \times 2{,}91 = 5{,}82 \text{ kNm.}$$

2. The drag force of the ship on the bollard
The ship is planned to be moored at the floating dock of Sanur with a Gross Tonnage (GT) of 116 tons. By looking at Table 3.4, it can be seen that the tensile force of this ship is 150 kN. Furthermore, the ship's pulling force on the bollard will be compared with the ship's pulling force due to currents and wind.

Table 5. Determination of the Ship's Tensile Force on the Bollard

Gross tonnage (GT) of vessel (tons)	Tractive force acting on a mooring post (kN)	Tractive force acting on a bollard (kN)
200 < GT ≤ 500	150	150
500 < GT ≤ 1,000	250	250
1,000 < GT ≤ 2,000	350	350
2,000 < GT ≤ 3,000	500	500
3,000 < GT ≤ 5,000	700	500
5,000 < GT ≤ 10,000	1,000	700
10,000 < GT ≤ 20,000	1,500	1,000
20,000 < GT ≤ 50,000	1,500	1,000

3. Wind load acting on the ship

Based on wind data collected from observations of the BMKG Ngurah Rai station in 2011-2020 (10 years), the analysis results that the dominant wind is southeast with a speed of 7-11 knots. So for calculating the wind force acting on the ship, wind with a speed of 11 knots or 5.7 m/s. Calculation of wind force using the following equation:

$$R_X = 0{,}5.\ \rho a \times U^2 \times A_T \times C_X$$
$$R_Y = 0{,}5.\ \rho a \times U^2 \times A_L \times C_Y$$

Information :

RX = Wind force in the X direction, in the direction of the ship (kN)

RY = Wind force in the Y direction, perpendicular to the ship (kN)

CX = Coefficient of direction X = 1.5 (see Table 3.5)

CY = Y direction resistance coefficient = 2,3 (see Table 3.5)

Table 6. Wind Resistance Coefficient

Square cross-section	2.0
〃	1.6
Rectangular cross-section (ratio of side lengths = 1:2)	2.3
〃	1.5
〃 (when one face is in contact with the ground)	1.2
Circular cross-section (smooth surface)	1.2

Pa = Density of the wind = 1.23 × 10-3 (t/m3)

U = Wind speed (m/s)

AT = The surface area of the ship above the water surface in the longitudinal direction (m2)

= Width × (depth-draft)
= 5.3 × 1 = 5.3 m2

AL = The surface area of the ship above the water surface in the transverse direction (m2)

= length of the whole ship (Loa) × (depth-draft)
= 26 × 1 = 26 m2

Then the calculation can be done:

R_X $= 0{,}5 \times \rho a \times U^2 \times A_T \times C_X$

R_X $= 0{,}5 \times 1{,}23 \times 5{,}7^2 \times 10^{-3} \times 5{,}3 \times 1{,}5 = 0{,}16$ kN

R_Y $= 0{,}5 \times \rho a \times U^2 \times A_L \times C_Y$

R_Y $= 0{,}5 \times 1{,}23 \times 5{,}7^2 \times 10^{-3} \times 26 \times 2{,}3 = 1{,}19$ kN

4. Current load acting on the ship

Based on the wind data shown in Figure 2.4, it is found that the current dominant moves to the northwest and southeast with a current speed of 2.5 – 5 cm/s. So the calculation of the current force acting on the ship using a current of 5 cm/s or 0.05 m/s. The equation for the current force is as follows:

$$Rf = 0{,}0014 \times S \times Vx^2$$
$$R = 0.5 \times \rho 0 \times C \times Vy^2 \times B$$

Information :

Rf = mooring load due to current direction parallel to the ship (kN)

R = The mooring load due to the direction of the current perpendicular to the ship (kN)

S = The area of the bottom surface of the ship that is fully submerged (m2)

= length of the entire ship (Loa) × width of the ship (B)
= 26 × 5.3 = 137.8 m2

Vx= Longshore current speed = 0.05 m/s

Vy= Current velocity perpendicular to the coast = 0.05 m/s

0= Density of seawater (t/m3) = 1.03 t/m3

C = Coefficient of current pressure = 2.1 (see Figure 3.6)

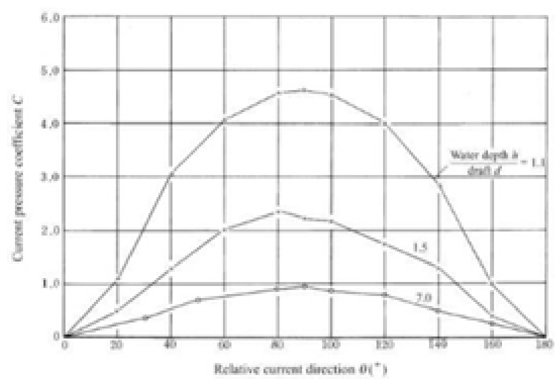


Figure 12. Current Pressure Coefficient

B = projected hull area below the water surface (m2)

= Loa length of ship × draft
= 26 × 1 = 26 m2

Then the following calculations can be performed:

$Rf = 0{,}0014 \times S \times Vx^2$

$Rf = 0{,}0014 \times 137{,}8 \times 0{,}0025 = 0{,}0005$ kN

$R = 0{,}5 \times \rho 0 \times C \times Vy^2 \times B$

$R = 0{,}5 \times 1{,}03 \times 2{,}1 \times 0{,}0025 \times 26 = 0{,}07$ kN

3.2 Fender and Bollard Criteria

3.2.1 Fender

1. Fender Type Selection

Based on the ship's collision force calculation, the maximum Ef obtained is 5.82 kNm. Then the fender system is planned to use Unit Elements. The fenders used are based on the Trelleborg Marine Systems catalog. Based on the description of the EU fender dimensions in table 3.6, the maximum Ef force can be accepted by one element with a length of 1m. So the ship collision force received by one EU fender element with a length of 1 m is:

$$Ef = \frac{5{,}82\ kNm}{1} = 5{,}82\ kNm$$

Based on the maximum Ef force that occurs in one element with the speed of the ship when moored (0.179 m/s), then the right fender was chosen, namely the UE RPD 250 fender with the ability to receive a force of up to 10.6 kNm and the resulting reaction of up to 103.8 kN.

Table 7. EU fender strength as per dimensions

			E0.9	E1.0	E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E1.7	E1.8	E1.9	E2.0
250	CV	E	8.1	9.0	9.3	9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.7	12.0
		R	79.0	88.0	90.0	93.0	95.0	98.0	100.0	103.0	106.0	108.0	111.0	113.0
	RPD	E_R	9.6	10.6	11.0	11.3	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2
		R_R	93.3	103.8	106.2	109.7	112.1	115.0	118.0	121.5	125.1	127.4	131.0	133.3
300	CV	E	11.7	13.0	13.4	13.8	14.2	14.6	15.0	15.4	15.8	16.2	16.6	17.0
		R	96.0	105.0	108.0	111.0	114.0	117.0	121.0	124.0	127.0	130.0	133.0	136.0
	RPD	E_R	14.7	15.2	15.7	16.1	16.6	17.1	17.6	18.0	18.5	19.0	19.4	19.9
		R_R	111.2	122.9	126.4	129.9	133.4	136.9	141.6	145.1	148.6	152.1	155.6	159.1
400	CV	E	21.0	23.0	24.0	24.0	25.0	26.0	27.0	27.0	28.0	29.0	29.0	30.0
		R	113.0	126.0	130.0	134.0	137.0	141.0	145.0	149.0	153.0	156.0	160.0	164.0
	RPD	E_R	24.4	26.7	27.8	27.8	29.0	30.2	31.3	31.3	32.5	33.6	33.6	34.8
		R_R	131.1	146.2	150.8	155.4	158.9	163.5	168.2	172.8	177.5	181.0	185.6	190.2
500	CV	E	31.4	36.0	37.1	38.2	39.3	40.4	41.5	42.6	43.7	44.8	45.9	47.0
		R	143.0	158.0	163.0	167.0	172.0	177.0	182.0	186.0	191.0	196.0	200.0	205.0
	RPD	E_R	37.4	41.6	42.9	44.1	45.4	46.7	47.9	49.2	50.5	51.7	53.0	54.3
		R_R	164.0	182.5	188.3	192.9	198.7	204.4	210.2	214.8	220.6	226.4	231.0	236.8
600	CV	E	40.0	44.0	45.0	47.0	48.0	49.0	51.0	52.0	53.0	54.0	56.0	57.0
		R	167.0	174.0	179.0	184.0	190.0	195.0	200.0	206.0	210.0	216.0	221.0	226.0
	RPD	E_R	46.6	50.8	51.8	54.1	55.3	56.4	58.7	59.8	61.0	62.1	64.4	65.6
		R_R	180.6	200.1	205.9	211.6	218.5	224.3	230.0	235.8	241.5	248.4	254.2	259.9
800	CV	E	47.0	52.0	54.0	55.0	57.0	58.0	60.0	62.0	63.0	65.0	66.0	68.0
		R	171.0	180.0	196.0	201.0	207.0	212.0	218.0	224.0	229.0	235.0	240.0	246.0
	RPD	E_R	53.6	60.3	61.6	62.7	65.0	66.1	68.4	70.7	71.8	74.1	76.2	77.5
		R_R	194.9	218.8	223.4	229.1	236.0	241.7	248.5	255.4	261.1	267.9	273.8	280.4

* In accordance with PIANC [Units: kNm, kN]
Values are for a single element, 1000mm long.
*Note:
1. CV: performance data at slow speed constant velocity (2-8 cm/min) compression at 23 ±5°C temperature and 0° compression angle.
2. RPD: Rated performance data, in accordance with PIANC with initial high speed berthing velocity 0.15 m/s.
RPD = CV (performance) x VF (velocity factor for Natural and Synthetic rubber blend) x TF (temperature factor) x AF (angle factor).
RPD is reported at 23 ±5°C temperature and 0° compression angle, therefore TF = 1, AF = 1.

Table 8. EU fender dimensions by type

Element	H	A	B*	C*	D	F	J	M	W	K	E	Anchors / Head bolts ^	Weight
UE250	250	109	114	71	20 - 27	152	33	25 - 35	218	50	300	M20	38
UE300	300	130	138	84	23 – 32	184	38	30 – 40	260	50	300	M24	54
UE400	400	165	187	102	25 - 35	248	41	30 - 40	330	250	500	M24	89
UE500	500	195	229	119	28 - 37	306	42	40 - 52	390	250	500	M30	135
UE550	550	210	252	126	32 – 38	338	42	40 – 52	420	250	500	M30	153
UE600	600	225	275	133	35 - 45	368	42	40 - 52	450	250	500	M30	179
UE700	700	270	321	163	35 - 45	428	56	50 – 65	540	250	500	M36	247
UE750	750	285	344	170	38 - 45	458	56	50 - 65	570	250	500	M36	298
UE800	800	300	368	178	38 – 45	488	56	50 – 65	600	250	500	M36	338
UE900	900	335	412	198	42 - 50	550	60	57 - 80	670	250	500	M42	410
UE1000	1000	365	458	212	46 – 58	610	60	57 – 80	730	250	500	M42	509
UE1200	1200	435	557	252	46 - 60	748	61	65 - 90	870	250	500	M48	717
UE1400	1400	495	642	281	50 - 65	856	67	65 - 90	990	250	500	M48	948
UE1600	1600	565	733	321	50 – 65	978	76	75 – 100	1130	250	500	M56	1236

* Asymmetrical bolting version only [Units: mm, kg/m]

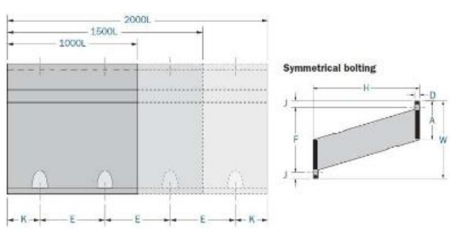


Figure 13. EU fender dimension description

Based on Table 3.7 and Figure 13, it is obtained:

a. Weight = 38 kg/m
b. Length = 1 m
c. Height = 0.25 m

2. Fender installation

The fender installation distance can be calculated using the following equation :

$$P \leq 2\sqrt{{R_B}^2 - (R_B - h + c)^2}$$

Information :
P = pitch of fender (distance between fenders) see Figure 13

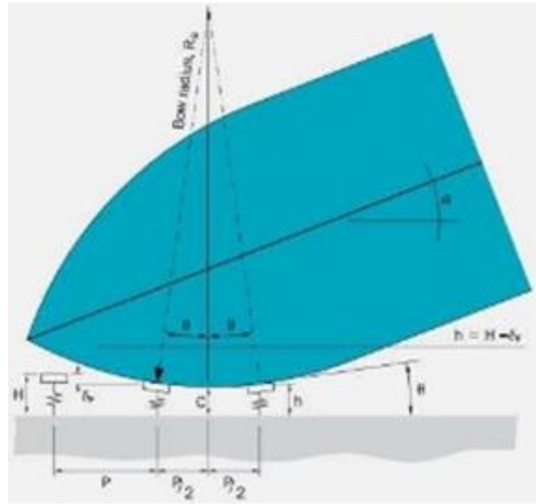


Figure 14. Determination of pitch of fender

RB = bow radius (m)
H = projection of the fender under pressure, measured at the centerline of the fender
C = distance between ship and wharf (C must be 5-15% of the projected fender not deflected, including fender panels)
Before knowing the fender installation distance, we need first to determine the RB:

$$R_B = \frac{1}{2}\left(\frac{B}{2} + \frac{Loa^2}{8B}\right)$$

Information :
B = width of the ship
Loa = length of the whole ship (m)

$$R_B = \frac{1}{2}\left(\frac{5{,}3}{2} + \frac{26^2}{8 \times 5{,}3}\right) = 9{,}29 \text{ m}$$

Next is to determine the fender deflection, whose magnitude can be seen in table 3.8.

Table 9. Deflection on Fender

D (%)	0	5	10	15	20	25	30	35	40	45	50	55	**57.5**	62.5
E (%)	0	1	5	12	21	32	43	54	65	75	84	95	**100**	113
R (%)	0	23	47	69	87	97	100	97	90	85	84	92	**100**	121

Then it can be analyzed that the deflection that occurs in the fender is:

$$E = \frac{5{,}82\ kNm}{10{,}6\ kNm} = 55\ \%$$

$$d = 35 + \frac{55 - 54}{65 - 54} = 35{,}1\ \%$$

Next, determine h :

$$h = H - defleksi = 0{,}25m - (0{,}25 \times 0{,}351)m$$
$$= 0{,}16\ m$$

Next, determine C :

$$C = 0{,}05\ \times H = 0{,}05\ \times 0{,}25 = 0{,}013\ m$$

So that it can determine the installation distance between fenders in the horizontal direction

$$P\ \leq 2\sqrt{9{,}29^2 - (9{,}29 - 0{,}16 + 0{,}013)^2}$$
$$P \leq 3{,}29\ m$$

Then the installation distance between horizontal fenders can follow the distance between the transverse portals of the pier, which is 2 m.

3.2.2 Bollard

1. Bollard Pull Force

Based on the calculation of the ship's pulling force on the bollard and the wind and current loads acting on the ship when it is moored, we can find out the following:

a. The ship's pulling force on the bollard = 150 kN

b. Longitudinal tensile force (due to wind and current) = 0.1605 kN

c. Tensile force transverse direction (due to wind and current) = 1.189 kN

It can be analyzed that the pulling force of the bollard used is the force due to the largest tug of the ship, which is 150 kN

2. Selection of bollard type

The selection of the bollard type is based on the Maritime International Bollard Catalog as follows:

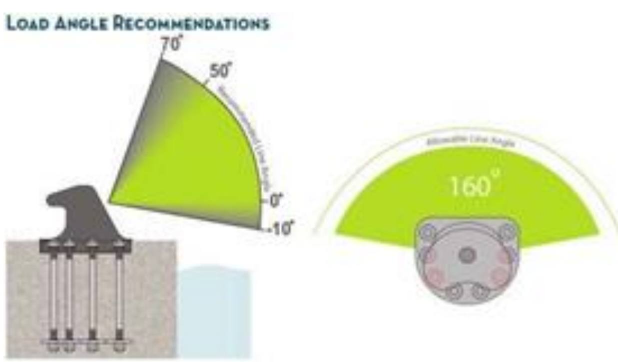
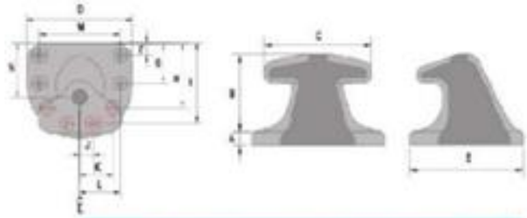


Figure 15. Angle of the pull of the load to the bollard.



Metric Dimensions (mm)	MT 10	MT 15	MT 20	MT 30	MT 50	MT 75	MT 100	MT 125	MT 150	MT 200
	Standard Bollard Capacity (Metric Tonnes)									
A	47	52	54	57	70	80	80	87	93	97
B	199	219	243	270	309	354	415	459	490	521
C	305	335	351	388	451	518	610	671	719	762
D	381	419	438	457	504	649	752	838	898	952
E	336	363	380	396	459	561	666	725	775	826
F	44	49	51	53	66	76	88	98	105	111
G	-	-	-	-	-	-	305	325	360	349
H	-	-	232	242	256	256	456	545	596	559
I	243	267	329	343	423	483	572	628	674	694
J	103	114	0	0	0	105	0	0	0	119
K	-	-	152	159	196	241	195	215	231	299
L	-	-	-	-	-	-	291	320	343	365
M	292	321	336	351	432	497	584	643	669	730
N	185	208	217	226	279	321	377	415	443	473
Bolt Size	M24	M24	M24	M30	M36	M42	M42	M48	M48	M56
Bolt Length	450	450	436	450	600	600	600	750	750	915
Bolt Qty	4	4	5	5	5	6	7	7	7	8

Figure 16. Bollard Dimension

In planning the floating jetty in Sanur, a T-Head MT 20 bollard can be used because the strength of the bollard can withstand a pull of up to 20 tons or 196.13 kN and has a fairly large pull angle.

3. Bollard Installation

The installation distance between the bollards in the horizontal direction follows the distance between the transverse portals of the pier, which is 2m.

3.3 Lateral bearing capacity of piles using the Broms method

Broms lateral bearing capacity is calculated to determine the stability of the soil and whether it will collapse or not. The Broms method is only used on one soil. If the soil has various layers, the dominant layer represents all layers. From the soil test data (geotechnical) RPI Sanur 2019, it was found that the dominant layer is sand.

a) Bore Log Data at Sea (BH-2)

Soil Type = Granular (sand)

Soil density (γ) = 20 kN/m3 (N-SPT value = 100)

Soil shear angle (ø) = 44 o (N-SPT value = 100)

Coefficient of soil variation (nh) = 34000 kN/m3

b) Pile Data

Pile Diameter (d) = 0.5 m = 50 cm

Pile Length (L) = 8 m = 800 cm

Concrete quality = 50 MPa

Ultimate moment = 285 kNm (PT. WIKA Beton)

3.3.1. Check pile stiffness due to lateral load

According to Broms, for piles in granular soils, the dimensionless factor L is associated with the following:

$$\alpha = \left[\frac{nh}{EpIp}\right]^{1/5}$$

nh = 34 kg/cm^3

Ep = 4700 $\sqrt{100}$

= 47000 kN/m^2 = 47 MPa = 479267 kg/cm^2

Ip = $\frac{1}{64}\pi(0,5)^4$ = 0,003 m^4 = 300000 cm^4

Therefore

$$\alpha = \left[\frac{34}{479267*300000}\right]^{1/5} = 0{,}0118$$

αL = 0,00118 * 800 = 9,44

αL > 4

It can be concluded that the pile behaves like a long pole (not stiff).

3.3.2 Calculating the magnitude of the lateral force

Ultimate moment resistance

$$\frac{Mu}{d^4 yKp} = \frac{285}{(0{,}5)^4 x20x2246} = 101{,}51 = 100$$

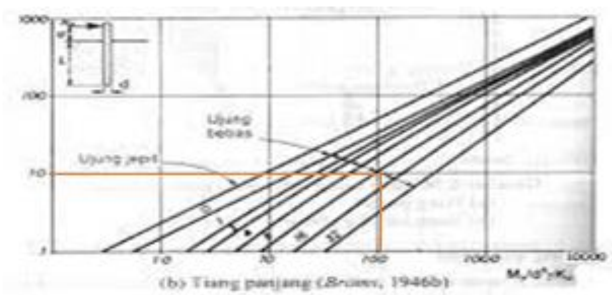


Figure 17. Graph of Maximum Moment Relationship with Ultimate Lateral Capacity

$$10 = \frac{Hu}{Kp \times y \times d3}$$

Hu = 56,15 = 5,721 ton

The ultimate lateral resistance value (Hu) is 5.721 tons or 5721 kg. Then, the permissible lateral force that is safe against soil and piles failure by taking the factor of safety F = 3 is

$H_{allowable}$ = Hu/F

$H_{allowable}$ = 5721/3

$H_{allowable}$ = 1907 kg

Then the value of the lateral force allowed for the long (not rigid) free end (free head) pile is H = 1907 kg.

3.4 Pile Deflection

The magnitude of the deflection of the long (non-rigid) pile with free ends can be calculated by:

$$yo = \frac{2{,}4\,H}{(nh)^{\frac{3}{5}}\,(EpIp)^{2/5}} + \frac{1{,}6\,H}{(nh)^{\frac{2}{5}}\,(EpIp)^{3/5}}$$

$$= \frac{2{,}4*1907}{(34)^{\frac{3}{5}}\,(479267*300000)^{2/5}} + \frac{1{,}6*1907}{(34)^{\frac{2}{5}}\,(479267*300000)^{3/5}}$$

$$= \frac{4576{,}8}{8{,}296*29045{,}543} + \frac{3051{,}2}{4{,}098*4950160{,}368}$$

=0,0189 + 0,00015

=0,01905 cm = 0,19 mm

According to Mc Nulty, buildings such as buildings, bridges, and other structures generally tolerate lateral movement between 6mm – 12mm. Thus, it can be concluded that the permit deflection meets the requirements of 0.19 mm.

3.5 Pile drop

3.5.1 Pile installation layout

Using AutoCAD 2018 software, the researcher made two pile installation layouts, both of which will be compared to the effect of soil changes or pile settlement. The work is based on Figure 3.6, Layout of the Sanur Floating Pier, to produce two layouts as follows:

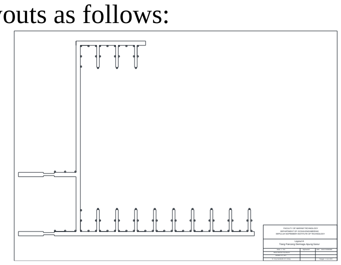


Figure 18. Layout A Pile Installation

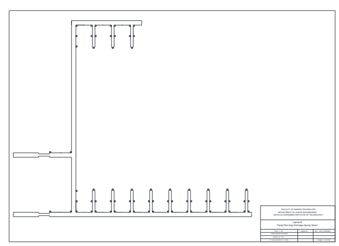


Figure 19. Layout B Pile Installation

Piles are indicated by a round shape installed in the gangway and a finger on the floating dock. The difference between Layout A and Layout B lies in the position of the pile installation and the number of piles used. The number of piles installed in Layout A is more than that of Layout B with different positions, as shown in the picture.

3.5.2 Land Modeling

By using Plaxis V.8.6, the researcher made soil modeling based on the previously created Pile Installation Layout. Soil modeling is plane strain geometry modeling 15 node elements, Mohr-Couloumb soil modeling. Pile material and soil are inputted based on the data used in this study.

After inputting soil material, piles, and others, a mesh generation is carried out so that the Soil Modeling view is obtained as follows:

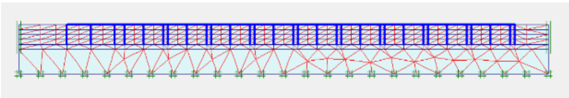


Figure 20. Land Modeling Layout A

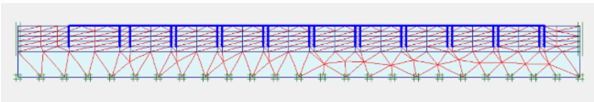


Figure 21. Land Modeling Layout B

Then the initial conditions are carried out for modeling the groundwater level. Next, calculate so that it produces Deformed Mesh Output as follows:

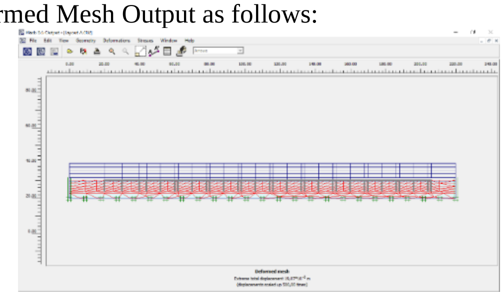


Figure 22. Output Deformed Mesh Layout A

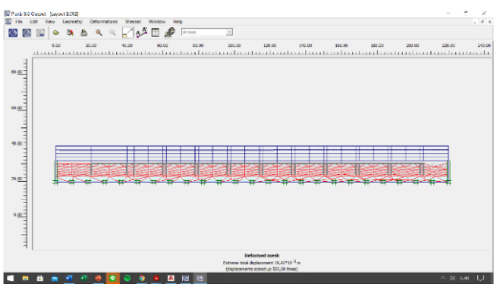


Figure 23. Output Deformed Mesh Layout B

The two outputs show that the Deformed Mesh Layout A is 19.07 mm, and the Deformed Mesh Layout B is 19.42 mm. It can be concluded that Layout B, with a higher number of piles, has a larger Deformed Mesh or soil change than Layout A. For the control of pile settlement itself, the structure is still said to meet the safety factor if the pile settlement occurs in less than 25 mm (<25mm). So it can be concluded that both Layout A and Layout B meet the safety factor.

4. CONCLUSIONS

Conclusions in this study include:
1. So that the floating dock can receive a maximum ship collision force (berthing force) of 5.82 kNm, the right fender selection is the UE RPD 250 fender with the ability to receive a force of up to 10.6 kNm, and the resulting reaction is up to 103.8 kN. Meanwhile, so that the floating pier can receive a bollard pulling force of 150 kN, a T-Head MT 20 type bollard can be used, which can withstand a pull of up to 20 tons or 196.13 kN.
2. The piles in the floating jetty are free-end and long (not rigid) piles with a permissible lateral force (H) of 1907 kg. In addition, the deflection of the piles is 0.19 mm, so it can be concluded that the floating dock piles meet the McNulty deflection tolerance requirements, ranging from 6-12 mm.
3. Pile Installation Layout A produces a Deformed Mesh of 19.07 mm, while Pile Installation Layout B produces a Deformed Mesh of 19.42 mm. It can be concluded that the greater the number of piles installed on the floating pier, the stronger the structure is, evidenced by the smaller pile settlement due to soil changes.

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