
PIANC AU-NZ
The Australian Northern Chapter of the World Association for Waterborne Transport Infrastructure
WORKSHOP
NAVIGATING THROUGH PIANC FENDER GUIDELINES 2024 (WG211) FOR DESIGNERS AND ASSET OWNERS
WED 30 JUL 2025 | 12:30PM - 5:30PM
ENGINEERS AUSTRALIA
LEVEL 9/340 ADELAIDE ST
BRISBANE QLD
MEMBERS $30
NON-MEMBERS $50
STUDENTS FREE

Acknowledgement of Country

PIANC

The World Association for Waterborne Transport Infrastructure

- PIANC AU-NZ acknowledges the Traditional Custodians of Country throughout Australia, including the land on which we gather and meet today, and recognises their continuing connection to land, waters, and community.
- We pay our respects to them, their cultures, and to elders past, present, and emerging.

PROGRAM

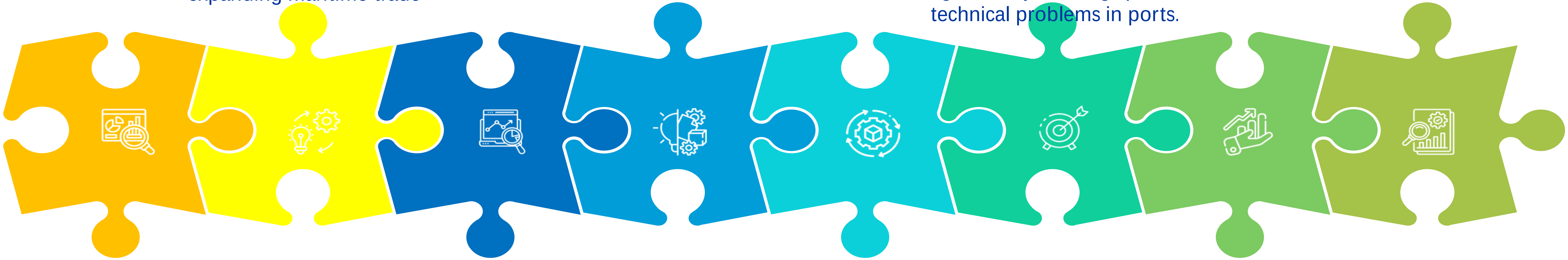
Arrival and Registration • Check-in and collect guest name badge	12:30 PM to 12:45 PM
Welcome and Introduction • Hari Panchumarthi	12:45 PM to 1:00 PM
Session 1 – Design Focus Module • Harvinder Singh	1:00 PM to 1:45 PM
Session 2 – Risk Management Module • Harvinder Singh	1:45 PM to 2:15 PM
Session 3 – Asset Owner Focus • Sam Mazaheri	2:15 PM to 2: 45 PM
Tea break	2:45 PM to 3:15 PM
Session 4 – Manufacturer Lens • James Curl • Adam Sellers	3:15 PM to 4:30 PM
Session 5 – Panel Discussion • Harvinder Singh • Sam Mazaheri • Adam Sellers • James Curl	4:30 PM to 5:30 PM
Networking	5:30 PM to 7:00 PM

Welcome and Introduction

- Hari Panchumarthi

PIANC - A Legacy of Leadership in Waterborne Transport

Where It All Began - A Historical Perspective



1869: Opening the Suez Canal and building the Cutty Sark

Illustrating the rapid evolution of maritime technology..

1885: First Navigation Congress in Brussels

Highlighting the growing need for international collaboration to address the challenges of expanding maritime trade

1902: Formal establishment of PIANC

Showcasing its enduring legacy as a global leader in waterborne transport infrastructure..

1914: Opening of the Panama Canal

Further demonstrating the impact of infrastructure development on global trade.

1950s Container Ships: Revolution in Sea Transportation

In 1956 the first shipload of fifty-eight containers sailed from Newark to Houston.

2000-2010

During the first decade of the 21st century, the size and number of cruise and container vessels increased significantly, causing specific technical problems in ports.

2002

First Navigational Congress was held in Australia (Sydney)

At the opening ceremony of Congresses, there usually is reference to the culture of the host country. In Sydney, 2002, an aboriginal didgeridoo player gave a demonstration of traditional Australian music. At this Congress there were individual papers only.

2024

Technological advancement, Climate change and its impact on coastal and maritime infrastructure

The Changing world – Transition to a Sustainable Maritime Future

Key global trends

- Population growth and increasing demand for maritime trade
- Climate change and its impacts on coastal and marine environments
- Technological advancements and the drive for innovation in maritime transport.

PIANC AU-NZ Northern Chapter

Northern Chapter – Events in 2024

1. March: QGHL Technical Talk & Site Visit
2. April: Challenges and Opportunities for Hydrogen in the Port Industry, EA Auditorium, Brisbane
3. 3 June: Recent Developments in Design of Breakwaters, Griffith University, Gold Coast
4. 27 June: YP Industrial Breakfast, WGA, Brisbane
5. 4 July: Darwin Seminar & Port Tour
6. 24 July: Fender New Guideline, WG211, Jacobs, Brisbane
7. 27-30 Aug: PIANC APAC 2024
8. October (early): Offshore Wind Seminar, QU, Brisbane
9. October (24): Gladstone Technical Seminar and Port Tour
10. November (late): Final Year Celebration followed by Xmas Drinks, Brisbane

Northern Chapter – Events in 2025

1. Feb: Smartship Australia simulator Facility Visit
2. May: Climate Change workshop: The Impact of Climate Change and Extreme Events on Port Infrastructure
3. Collaboration with universities: UQ, CQU, Griffith
4. 19 June: Concrete Maintenance and Durability in Maritime Infrastructure
5. 2 July: Menard Oceania – Brisbane Site Tour and Networking
6. 30 July: Navigating through New Fender Guideline (WG211) – half-a-day
7. 18-21 Aug: Coasts and Ports
8. 16 Oct: Sustainability in Ports and Working with Nature (Darwin)
9. 30 Oct : YP Leadership Breakfast
10. Nov (late): Year End Celebration followed by Xmas Drinks, Brisbane

SESSION 1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Session 1 – Design Focus Module
Session 2 – Risk Management Module

Harvinder Singh

Principal Maritime Engineer, Jacobs

Harvinder Singh's presentation on the PIANC WG211 Report will offer a clear and practical guidance on the design, assessment, and risk management of fender systems—addressing both current challenges and emerging opportunities in the maritime sector.

Developed through global collaboration and expert consensus, the WG211 Report represents a comprehensive and forward-looking framework. While it began as an update to the 2002 WG33 Guidelines, the final document is a complete overhaul and now stands as a new, standalone guideline—fully superseding its predecessor.

Harvinder Singh is a Principal Engineer at Jacobs with over 20 years of experience in ports and maritime infrastructure. Harvinder represented PIANC AU-NZ on the PIANC MarCom Working Group 211, contributing to key sections of the report including design, testing, and manufacturing of marine fender systems.

He is a Fellow of Engineers Australia and a Board Member of PIANC AU-NZ, known for his innovative approach and commitment to advancing engineering standards in the maritime sector. He is passionate about leveraging innovation to solve complex challenges in our industry and continues to be a driving force in shaping the future of maritime infrastructure.

Navigating through PIANC Fender Guidelines (WG211)

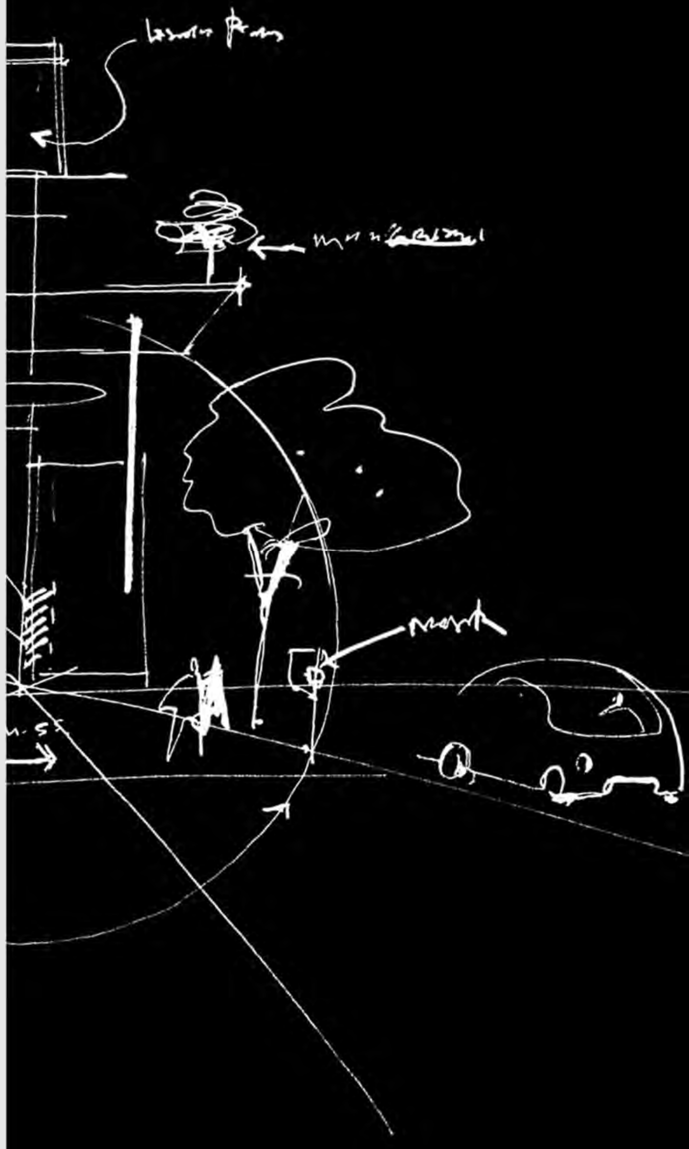
Session 1:
Design Focus Module

Harvinder Singh
Principal Engineer,
Jacobs

Challenging today.
Reinventing tomorrow.

Program

1. Introduction and overview of WG211
2. Principles of fendering
3. Berthing energy: navigation conditions, approach velocity, and angles
4. Use of partial safety factors and probabilistic design approaches
5. Worked example
6. Selection of a fender system
7. Fenders under moored conditions
8. Ship-to-ship berthing
9. Fender system component design: panels



The latest 2024 Fender Guidelines by PIANC

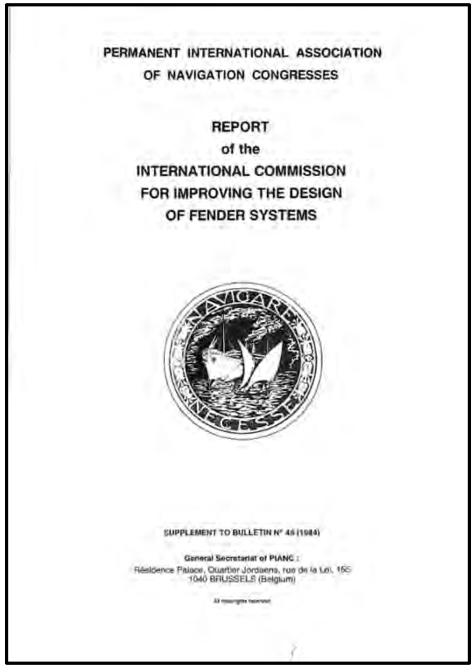
Background – Who's PIANC MarCom WG211

Jacobs
Royal HaskoningDHV — Enhancing Society Together
AECOM
SGH
moffatt & nichol
Siport21
WAVES GROUP
CDIT — COASTAL DEVELOPMENT INSTITUTE OF TECHNOLOGY
BRIDGESTONE
TRELLEBORG
SHIBATA FENDER TEAM — on the safe side
prosertek — HARBOUR EQUIPMENT
BESIX
Port of Rotterdam
BREMEN BREMERHAVEN — ZWEI STÄDTE. EIN HAFEN.
ExxonMobil
Boskalis
鳥取大学 Tottori University

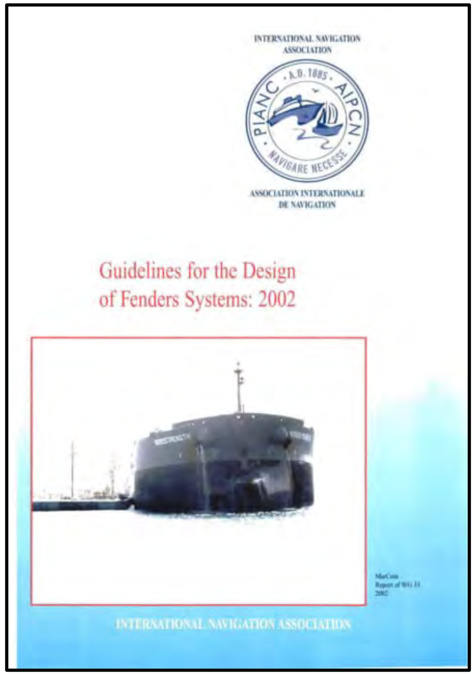
The latest 2024 Fender Guidelines by PIANC

Background – Fender Design Guidelines

In 1984 PIANC published a Supplement to Bulletin No. 45, containing improved design methods for fender systems (18 years);



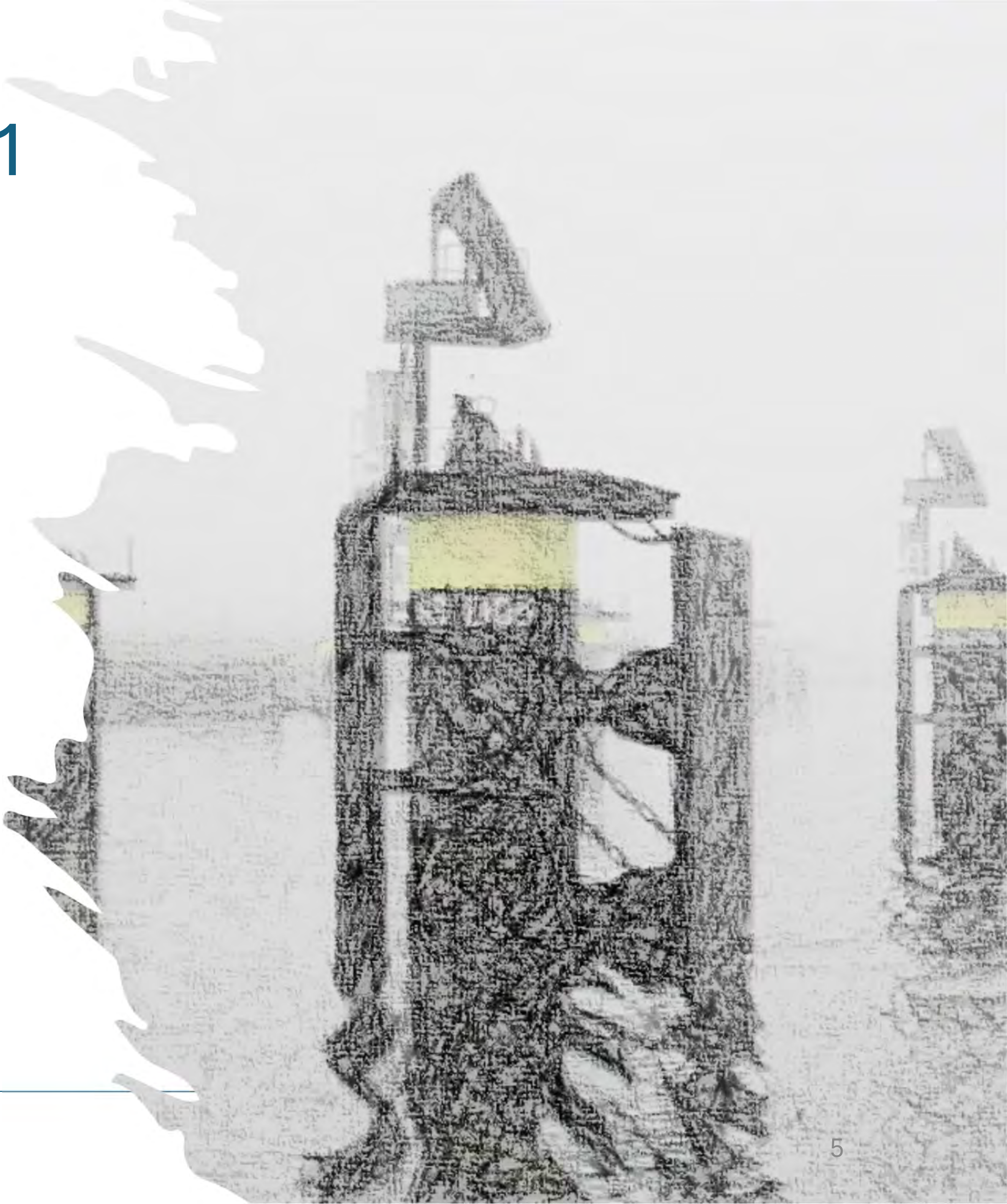
In 2002, PIANC formed WG33, which included more advanced fender design and testing methods – current design guidelines (22 years+2 years transition);



In March 2024, PIANC published WG211, which is a new guidelines rather than and update to WG33 (4 months and counting);

Introduction: The Aim of WG211

- Ensures fender systems are safe, **reliable**, **durable**, and cost-effective.
- Covers design, **manufacturing, testing**, and **installation**.
- This is a new guidelines – Not just **an update** of WG33.
- Cannot simply replace WG 33 with WG 211; a **complete redesign** is necessary due to the fundamentally different approach.
- Greater emphasis **on Site-Specific Data**
  - Recommends the need to gather and **include local berthing data**;
  - Default values should only be used when **no site-specific data** is available



Introduction: General Aspects of WG211

- Potential for Cost and Size Optimisation
  - When **site-specific data is used**, fenders may be smaller and more cost-effective than those designed under WG 33.
  - Ignoring local data may lead to **overdesign** and unnecessary **costs**.
- Scope and Focus:
  - Applies to **seagoing vessels** (mostly tug-assisted or thruster-equipped).
  - **Not intended** for collision scenarios.
- Transition Period - Ends on 1 May 2026.
  - Time allowed for suppliers to **update catalogues** and complete **type approval testing**.

Introduction: Key Takeaways

Designers & Engineers

- WG 211 is not a simple update of WG 33.
- Requires site-specific data for cost-effective fender sizing.
- Emphasises integrated design of the entire marine structure, not just the fender.
- Partial safety factors are tailored for new structures—use caution for existing assets.

Introduction: Key Takeaways

Designers & Engineers

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Port Authorities & Operators

- WG 211 promotes greater safety and reliability in berthing operations.
- Transition period ends 1 May 2026—plan procurement and approvals accordingly.
- Engage local experts (pilots, tug masters) to inform design inputs.

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Manufacturers & Suppliers

- Need to update product catalogues and undergo type approval testing.
- Fender systems must meet new performance and testing standards.
- Collaboration with designers is essential to align with WG 211 requirements.

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Project Managers & Procurement Teams

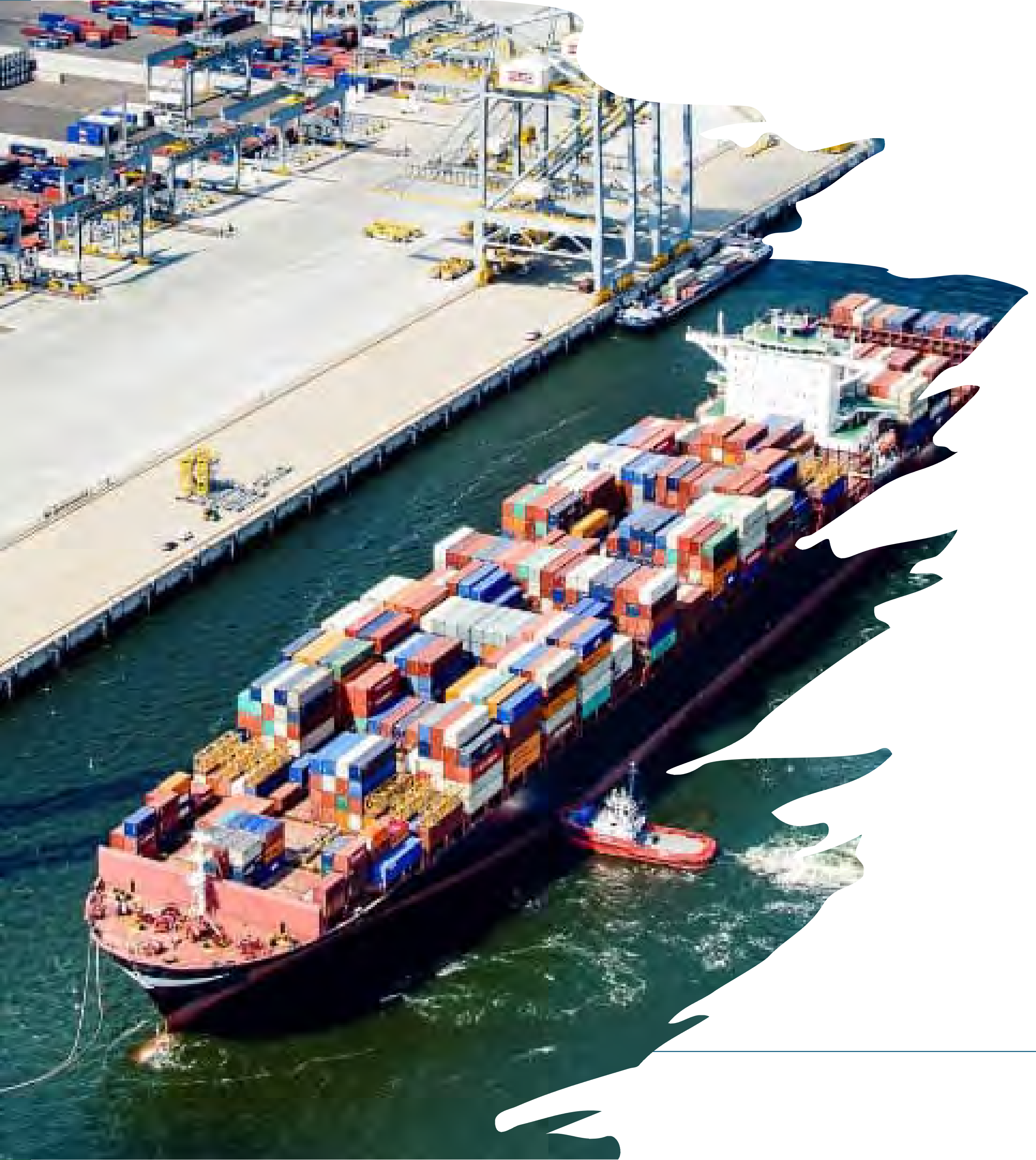
- WG 211 is not a contractual document—should be used as a technical reference.
- Ensure specifications clearly distinguish between WG 33 and WG 211.
- Be aware of cost implications due to changes in design methodology.

Berthing Energy: Navigation Conditions

- Classification Criteria
  - Favourable: All conditions in the "**favourable**" column are met.
  - Unfavourable: If any one condition in the "**unfavourable**".
  - Moderate: Conditions that are neither fully favourable nor unfavourable.
- Navigation condition must be **agreed** with the asset owner before starting fender design.
- If two or more unfavourable factors are present:
  - A **detailed study is** recommended.
  - Ideally confirm vessel control and define safe environmental thresholds.
- Operational Impact - Unfavourable conditions also affect mooring and loading safety.

		Navigation Conditions		
		Favourable	Moderate	Unfavourable
Operational Impact	**Vessel approach strategy**	The vessel can be brought to a controlled stop during the final berthing manoeuvre; AND	Vessels cannot be brought to a controlled stop during the final berthing manoeuvre, e.g. manoeuvring onto the berth by making use of the vessel momentum; OR	The capability to control the vessels approach, even with tug assistance, is significantly affected by the environmental conditions; OR
Operational Impact	**Resources for Vessel Control** (main propeller, rudder, azipods, bow/ stern thrusters, tugs, etc.)	The vessel's movement can be fully controlled using the available resources, with margin. ; AND	The vessel's movement can be controlled using the available resources; however, environmental conditions are elevated and require active/continual use of the available resources to maintain control, margin is reduced. If neither tugs nor thrusters are present, this category may apply for benign environmental conditions.; OR	Environmental forces are significant compared to the available resources for controlling the vessel's movements, approaching limits of control. If neither tugs nor thrusters are present, this category may apply for moderate environmental conditions.; OR
Environmental Impact	**Currents**	During the berthing process currents at oblique angles or parallel to the berth having minimal effect on the manoeuvring vessel. Current forces are small and marginally effect the efficiency of the available tug power and/or vessel propulsion; AND	During the berthing process currents are generally parallel to the berth, however, may require continuous use of elevated vessel propulsion and/or tug power to stabilise control of the vessel in its final approach. Oblique current forces are controllable by available tug power and/or vessel propulsion; OR	During the berthing process, strong currents e.g. turbulent currents, at an oblique angle or parallel that require substantial use of propulsion to control the vessel; OR
Environmental Impact	**Waves**	During the berthing process wave effects on both the berthing vessel and the assisting tugs are negligible; AND	During the berthing process wave effects on the berthing vessel are small, however, the effectiveness of the tug assistance may be reduced; OR	During the berthing process waves substantially influence both the berthing vessel and the assisting tugs; OR
Environmental Impact	**Wind**	During the berthing process wind speeds and/or windage area result in small wind forces that marginally reduce the effectiveness of the available tug power and/or vessel propulsion.	During the berthing process wind speeds and/or windage area result in moderate wind forces that reduce the effectiveness of the available tug power and/or vessel propulsion.	During the berthing process wind speeds and/or windage area result in high wind forces that substantially reduce the effectiveness of the available tug power and/or vessel propulsion.

Table 5-1: Description of navigation conditions at berth



Berthing Energy: Vessel Approach Velocity

Key findings PIANC WG145:

- Historical data suggesting a correlation between berthing velocities and vessel sizes **can't be confirmed**. Therefore, applying these velocity curves to large seagoing vessels may pose **safety risks**.
- No evidence that **berthing velocity is directly influenced by the type of marine structure**, type of fender system, UKC, number of tugs etc.
- **No direct correlation** between environmental factors (wind and current) and **berthing velocity** was found.
- Berthing velocities **strongly depend on berthing procedures** in place (type of landing, experienced and well-trained pilots, tug assistance, berthing aid systems, etc.)

Berthing Energy: Vessel Approach Velocity

When **<u>no information</u>** available

- Designers can use this table.
- Velocities are slightly conservative

In circumstances that there are concerns about the validity of the values in Table 5-3, e.g. the berthing velocity is considered to be excessively high it is recommended to rely on local information and other relevant experience to determine an appropriate characteristic berthing velocity instead of using the values from table 5-3.

Navigation Condition:	Favourable	Moderate	Unfavourable
Type of vessel	$V_{B,c}$ (m/s)		
Passenger and vehicle ferries	0.400	0.500	0.600

Table 5-4: Characteristic longitudinal berthing velocity in the absence of site-specific information

Navigation Condition:	Favourable	Moderate	Unfavourable
Type of Vessel[a]	$V_{B,c}$ (m/s)		
Coaster	0.180[f]	0.300[e]	0.400[e]
Feeder, Handysize	0.150[b]	0.225[c]	0.300[d]
Handymax, Panamax	0.120[b]	0.200[e,g]	0.275[d]
Vehicle Carriers	0.120[e]	0.200[e]	0.275[e]
Post Panamax, Capesize (small), Aframax	0.100[b,e]	0.175[c]	0.275[d]
New Panamax, Capesize (large), Suezmax, ULCV, VLBC, VLCC, ULCC	0.100[b,e]	0.150[c,f]	0.250[d]
Cruise & Passenger Vessels	0.100[e]	0.150[e,f]	0.250[e]

a. Typical vessel dimensions: Coaster (5,000-15,000 DWT), Feeder, Handysize (15,000-42,000 DWT); Panamax, Handymax (42,000-85,000 DWT); Post Panamax, Capesize, Aframax (85,000-115,000 DWT); New Panamax, Capesize, Suezmax (115,000-170,000 DWT); ULCV, VLBC, VLCC, ULCC (>170,000 DWT). For vessels not listed in the table (e.g. LNG) use equivalent size. Although most gas tanker owners have their own global data set.
b. These recommended berthing velocities are largely based on field measurements in Rotterdam and Wilhelmshaven, (PIANC WG145, 2022), (Roubos, Gaal, Hein, Iversen, & Williams, 2022).
c. These recommended berthing velocities are largely based on the normal navigation conditions distinguished by PIANC WG 145 (PIANC WG145, 2022) and verified by WG 211 against new data sets from Poland, Korea, US and India.
d. These recommended berthing velocities are largely based on the measurements conducted in Bremerhaven, (PIANC WG145, 2022), (Roubos, Gaal, Hein, Iversen, & Williams, 2022).
e. These recommended berthing velocities are based on interviews with masters, pilots, harbour masters and experienced port engineers. The values are based on comparison with similar vessel sizes.
f. These recommended berthing velocities are based on EAU 2012 and ROM 2.0-11 (2012).
g. Some unpublished berthing records, of berths claiming to be moderate, include slightly higher velocities. BS6349 and WG 211 consider this value to be sufficient for the majority of berths.

Table 5-3: Characteristic berthing velocity in the <u>absence</u> of site-specific information

Jacobs

Berthing Energy: Vessel Approach Velocity

Key Takeaways

WG 211 describes the berthing process of a large vessel more accurate than WG 33.

Correctly using WG 211 will provide a berth with optimal fenders. Often slightly more economical than under WG33.

Correct use means using as much local data and experience as possible.

The designers should always talk with potential users like masters, pilots, harbourmasters if present

Berthing Energy: Berthing Angles

Why Berthing Angles Matter ?

- Affects how much **energy the fender system must absorb**, the larger the angle the higher the impact force.
- Incorrect angle assumptions can lead to **damage** to the **vessel hull**, fender units, or **the berth structure**.
- Influences Fender Selection and Placement - determines the type, size, and layout of fenders needed.
- Helps **identify high-risk berthing scenarios** where additional safety measures or studies are needed.
- Supports Operational Planning - guides decisions on berth usage, vessel types, and environmental limits for safe operations.

Alongside berthing	Tugs	Thrusters[a]	α_c[b]	α_l[c]	Explanation
Parallel, (Section 5.1.1)	Yes	Yes	2	3	Vessels positioned off the berth and approach parallel. Vessels have sufficient thruster capacity. **If under keel clearance is very low and therefore it negatively influences manoeuvrability (local input needed),consider this as a 'no thrusters scenario'.**
		No	3	5	Vessels positioned off the berth and approach parallel. Vessels do not have thrusters **or very low under keel clearance negatively influences manoeuvrability.**
	No	Yes	2	3	Vessels positioned off the berth and approach parallel. Vessels have sufficient thruster/pod capacity on bow and stern (like cruise vessels).
		No	X	X	This manoeuvre can only be done using a current or strong wind. To be discussed with pilots and vessel masters.
Angular (Section 5.1.1)	Yes	Yes	3	5	Vessels have a large angle during the approach. Local current or wind is used to berth the vessel. However, at the moment of fender contact the berthing angle is low. Vessels have sufficient thruster capacity.
		No	4	7	Vessels have a large angle during the approach. Local current or wind is used to berth the vessel. However, at the moment of fender contact the berthing angle is low. Vessels do not have thrusters **or under keel clearance is very low and therefore negatively influences manoeuvrability.**
	No	Yes	8	15	Smaller coastal vessels perform an angular approach, landing using spring lines and pushing the bow or stern in with engine and rudder. Vessels have some thruster capacity.
		No	10	20	Smaller coastal vessels preform an angular approach, landing using spring lines and pushing the bow or stern in with engine and rudder. Vessels have little or no thruster capacity.

a. Manoeuvrers with thrusters are more controlled and directly in the hand of the master.
b. Characteristic berthing angle to be used in the design
c. Upper limit of the berthing angle to ensure that the fender pitch is adequate (see Chapter 0)

Table 5-5: Berthing angle [degrees] at the moment of contact, no site-specific information available

Partial Safety Factors & Probabilistic Design Approaches

Key Features

- Provides clear guidance on **adjusting berthing energy** factors based on:
  - Specific berthing conditions
  - Variations in vessel size
  - Safety classification and potential consequences of fender failure
- New additions in WG 211:
  - Accounts for **uncertainties** in fender performance
  - Considers **multiple fender contact** scenarios
  - Includes temperature effects on fender behaviour
- Overall Benefit:
  - A more transparent, practical, and user-friendly guideline compared to WG 33

Partial Safety Factors & Probabilistic Design Approaches

WG211 Approach:

- Move from a **Deterministic** Approach to **Probabilistic** Approach
- Develop safety classes similar to those used in **Eurocode or ASCE 7**
- Use a rational approach similar to **LRFD or Partial Load Factors** – with energy instead of force
- Include uncertainties in **fender performance**, multiple fender contact, temperature
- Develop specific guidance for contributing factors
- Ensure consistent targeted levels of safety
- Partial load factors are based on a 50-year return period (5000 breathings, 100 per year)
- A different arrival frequency will have a DIRECT impact on the load factors

Navigation Condition	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Favourable	High	1.30	1.50	1.60	1.70
	Moderate	1.35	1.55	1.65	1.80
	Low	1.50	1.70	1.80	1.95
Moderate	High	1.35	1.60	1.70	1.85
	Moderate	1.45	1.65	1.75	1.90
	Low	1.60	1.80	1.90	2.10
Unfavourable	High	1.50	1.85	2.00	2.20
	Moderate	1.60	1.95	2.05	2.30
	Low	1.80	2.15	2.30	2.55

Table 5-8: Reference partial energy factor[$\gamma_{E_{ref}}$] for 100 berthings per year – single fender contact

Navigation Condition	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Favourable	High	1.15	1.35	1.40	1.50
	Moderate	1.20	1.40	1.55	1.55
	Low	1.35	1.50	1.60	1.70
Moderate	High	1.20	1.40	1.45	1.60
	Moderate	1.25	1.45	1.55	1.65
	Low	1.40	1.60	1.70	1.80
Unfavourable	High	1.25	1.55	1.65	1.85
	Moderate	1.35	1.60	1.75	1.95
	Low	1.50	1.80	1.95	2.15

Table 5-9: Reference partial energy factor[$\gamma_{E_{ref}}$] for 100 berthings per year – multiple fender contact

Monitored berthing	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Single fender contact	High	1.25	1.40	1.45	1.55
	Moderate	1.30	1.45	1.50	1.60
	Low	1.40	1.55	1.65	1.75
Multiple fender contact	High	1.10	1.25	1.30	1.40
	Moderate	1.15	1.30	1.35	1.45
	Low	1.30	1.45	1.50	1.60

Table 5-10: Reference partial energy Factor [$\gamma_{E_{ref}}$] for 100 berthings per year – for Monitored Berthings

Partial Safety Factors & Probabilistic Design Approaches

Class	Description of failure consequences	Explanation	Example of fender systems
A	Negligible/ low consequences for risk of loss of human life AND environmental damage AND economic damage.	Failure of a single fender predominantly results in insignificant to no structural damage.	Fenders installed on a marine structure that is part of a terminal or port with functional redundancy [a] and limited number of people at risk. Failure of a single fender is not likely to result in the unavailability of the berth or widespread damage to the marine facility assuming there is sufficient redundancy with additional berths. An example can be a continuous earth retaining quay wall or a dolphin berth with more than two/ redundant berthing (breasting) dolphins or marine facilities with multiple berths having similar capabilities.
B	Some consequences for risk of loss of human life OR environmental damage OR economic damage.	Material damage **and** functionality losses of significance for owners and operators **and** low or no social impact.	Fenders installed on a marine structure without functional redundancy [a]. Failure[b] of the fender system is likely to result in the unavailability of the berth with no other alternatives. An example can be a single berth with two berthing (breasting) dolphins.
C	Considerable consequences for risk of loss of human life OR environmental damage OR economic damage.	Material losses **and** functionality losses of societal significance, causing regional disruptions **and** delays in important societal services over several weeks.	Fenders installed on marine structures, positioned at locations for which failure of the fender system is likely to put public lives at risk. Fenders installed on a marine structure for which failure[b] of the fender system is likely to close the berth and cause considerable consequential economic loss. Examples can be essential floating powerplants or floating storage regassification units that are prevented from operating after fender failure[b] and sufficient backup measures are available to resume operations.
D	High risk of loss of human life OR environmental damage OR economic damage.	Disastrous events causing severe losses of societal services **and** disruptions **and** delays at national scale over periods in the order of months.	Fenders installed on marine structures for which failure[b] of the fender system is likely to lead to significant socio-economic disruptions. Examples are progressive damage or cascading effects of other types of structures, e.g. critical installations such as essential powerplants or floating storage regassification units that are prevented from operating after fender damage with no backup measures available to resume operation.
E	Very high risk for loss of human life OR environmental damage OR economic damage.	Catastrophic events causing losses of societal services **and** disruptions **and** delays beyond national scale over periods in the order of years.	Beyond the scope of this guideline. In some cases, owners may choose, for practical reasons, to add an additional berthing criterion to cover 'Extreme Events' where additional energy is absorbed by partial collapse of secondary structural elements to protect critical wharf assets.

a) If a structural component is part of a series system (a configuration such that, if any one of the system components fails, the entire system fails) or if progression of failure is not mitigated, a higher consequence class should be considered.

b) A fender system is therefore considered to fail when it does not fulfil its function (Chapter 2.1), resulting in a high probability of exceeding the design value of the fender reaction force and/or the design value of the associated berthing impact force. Fender system failure can happen even if fender units still appear intact and undamaged for future use. Other causes of failure can be damage due to degradation or mechanical failure of the fender system itself.

Table 4-1: Consequence classes and description of failure consequence

Berthing Energy: WG33 vs WG211

Design Approach

<u>WG33</u>

Global safety factor

$$E_d = \left(\frac{1}{2} M V_B^2\right) C_e C_m \boldsymbol{C_s C_c}$$

$$E_{ab} = C_{ab} E_d$$

Select a fender unit

Adjustments for temperature, angle, and velocity;
E_f
$E_f \geq E_{ab}$

<u>WG211</u>

Load and resistance factor

$$E_{k,c} = \left(\frac{1}{2} M V_B^2\right) C_e C_m$$

$$E_{k,d} = \gamma_E E_{k,c}$$

8-step approach for γ_E

Select a fender unit; E_{base}

Adjustments for temperature, angle, and velocity;
$E_{f,c}$

$$E_{f,d} = \frac{E_{f,c}}{\gamma_m}$$

$$E_{f,d} \geq E_{k,d}$$

fender performance
multiple fender contact

Ce = Eccentricity Factor
Cm = Added Mass Factor
Cs = Softness Factor
Cc = Cushion Factor

Worked Example : Based on WG211

Vessel and Navigation Conditions

Parameters	Scenario 1	Scenario 2	Scenario 3
Berthing Input			
Consequence Class	Class A	Class C	Class B
Navigation Condition	Moderate	Moderate	Favourable
Tugs	No	Yes	No
Thrusters	No	No	Yes
Vessel Properties			
Type of Vessel	Panamax	Capesize	Handysize
M (t)	94,000	118,800	25,500
L_{BP} (m)	228	293	152.4
B (m)	32.2	47	25.6
D (m)	12.2	10	9.3

Worked Example: WG211

Berthing Energy

Parameters	Scenario 1	Scenario 2	Scenario 3
Site Specific Data?	No	Yes	Yes
Berthing Velocity (m/s)	0.200 (WG211 – Table 5-3)	0.150	0.160
Berthing Angle (^{o})	10 (WG211– Table 5-5)	10	8 (WG211– Table 5-5)
Partial Energy Factor	2.04 (WG211 – Sec 5.8)	1.87 (WG211 – Sec 5.8)	2.00 (WG211 – Sec 5.8)
Design Berthing Energy (kNm)	**3,632**	**2,323**	**1,489**
Fender Size Required	**SCN 1600 F2.1**	**SCN 1800 F1.7**	**SCN 1150 F1.7**

Comparison b/w WG211 and WG33

Scenario 1

Parameters	WG 211	WG33
Berthing Input	Consequence Class = Class A Navigation Condition = Moderate Tugs = No Thrusters = No	Berthing Condition = c

Parameters	WG 211	WG33
Site Specific Data?	No	No
Berthing Velocity (m/s)	0.200	0.150
Berthing Angle (°)	10	10
Partial Energy Factor/Abnormal Energy Factor	2.04	1.5
Design Berthing Energy (kNm)	**3,632**	**1,888**
Fender Size Required	**2 x SCN 1600 F2.1**	**2 x SCN 1400 F1.2**

Comparison b/w WG211 and WG33

Scenario 2

Parameters	WG 211	WG33
Berthing Input	Consequence Class = Class C	Berthing Condition = d
	Navigation Condition = Moderate	
	Tugs = Yes	
	Thrusters = No	

Parameters	WG 211	WG33
Site Specific Data?	Yes	Yes
Berthing Velocity (m/s)	0.150	0.150
Berthing Angle (°)	10	10
Partial Energy Factor/Abnormal Energy Factor	1.87	1.5
Design Berthing Energy (kNm)	**2,323**	**1,795**
Fender Size Required	**SCN 1800 F1.7**	**SCN 1800 F0.9**

Comparison b/w WG211 and WG33

Scenario 3

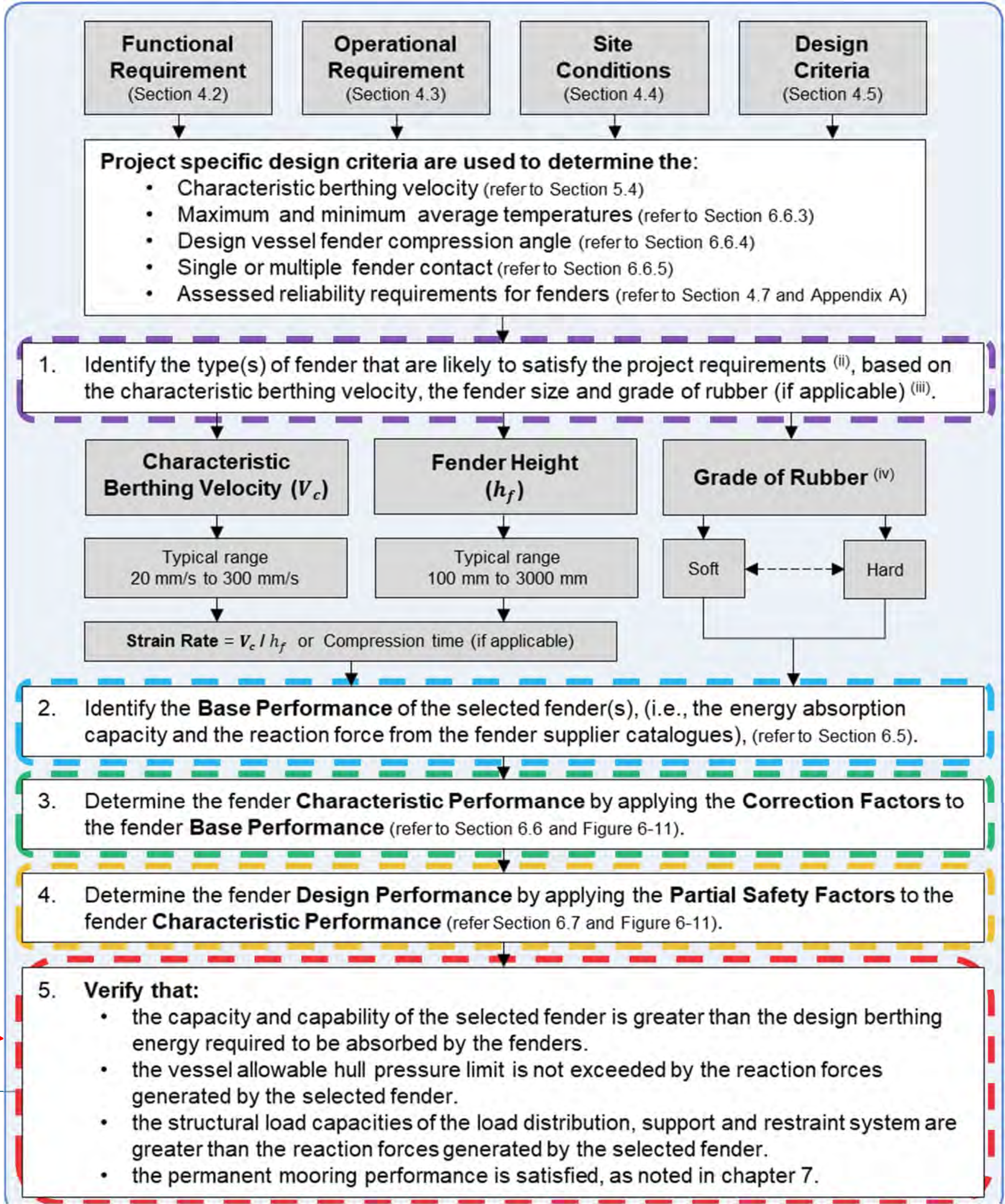
Parameters	WG 211	WG33
Berthing Input	Consequence Class = Class B Navigation Condition = Favourable Tugs = No Thrusters = Yes	Berthing Condition = c

Parameters	WG 211	WG33
Site Specific Data?	Yes	Yes
Berthing Velocity (m/s)	0.16	0.200
Berthing Angle (º)	8	10
Partial Energy Factor/Abnormal Energy Factor	2.00	1.5
Design Berthing Energy (kNm)	**622**	**729**
Fender Size Required	**SCN 1150 F1.7**	**SCN 1200 F1.4**

Selection of Fender System

WG211 Figure 6-1; Page 69

- Select an initial fender
- Base performance
- Characteristic performance
- Design performance
- Verify acceptability of fender



Selection of Fender System

- Application & **vessel** types
- **Operational** factors
- **Experience**/judgement
- Site specific criteria

Fender Types

Vessel Types

Vessel Types \ Fender System Types	Arch	Cell	Cone	Cylindrical	Donut	Element	Extruded	Foam	Hydropneumatic	Parallel Motion	Pile	Pneumatic	Roller	Wheel
Bulk Carriers	○	●	●	●		○				○	●			
Car Carriers		●	●	○		●				○	○			
Container Vessels	●	●	●	●		○					●			
Cruise Vessels		●	●	○		●		●	●		○	●		
Fast Ferries		●	●			●				○	○			
Fishing Vessels	●			○							●			
Gas Carriers		●	●	○		○		○	○	●	●	○		

Fender Types

Applications

Applications \ Fender System Types	Arch	Cell	Cone	Cylindrical	Donut	Element	Extruded	Foam	Hydropneumatic	Parallel Motion	Pile	Pneumatic	Roller	Wheel
Belted vessels	○	●	●	○	●	●	○	○	○	●	○	○	○	○
Continuous berth	●	●	●	●		●	●	●	○	○	○	●		
Dolphin	○	●	●	○	●	●	○	○	○	●	●	○		
Ice Zones	○	●	●	○		●	○	○			○		○	○
Large bow flares		●	●	○	●	●		●	○			●	○	○
Large tidal zones	○	●	●	○	●	●	○	●	●	●	●	●	○	○
Lay-by berths	●	○	○	●	●	●	○	○	●	○	●	●	○	○

● Generally considered suitable for this vessel type.

○ Suitable for some vessels. Potential limits to be considered.

(blank) Generally not considered suitable for this vessel type except in special applications.

Selection of Fender System

performance data at slow speed constant velocity (2-8 cm/min) compression at 23 ± 5°C temp & 0° angle.

Base Performance vs. Characteristic Performance

- What is "Base Performance"?
- Property of a particular fender, from a particular manufacturer.
- Same as CV in WG33. This is the value "as tested"
- From the catalogue, identify the following

E_{base} Base energy absorption

R_{base} Base reaction force

Correction Factors

- Velocity Factor (C_v)
- Temperature Factor (C_t)
- Angular Factor (C_{ang})

Reported by manufacturer test data, applied by designer.

- Multiple Fender Contact Factor (C_{mult})

Calculated by designer

Application of Correction Factors:

$$E_{f,c} = \boldsymbol{E_{base}}\ C_{v,c}\ C_{t,c}\ C_{ang,c}\ C_{mult,c}$$

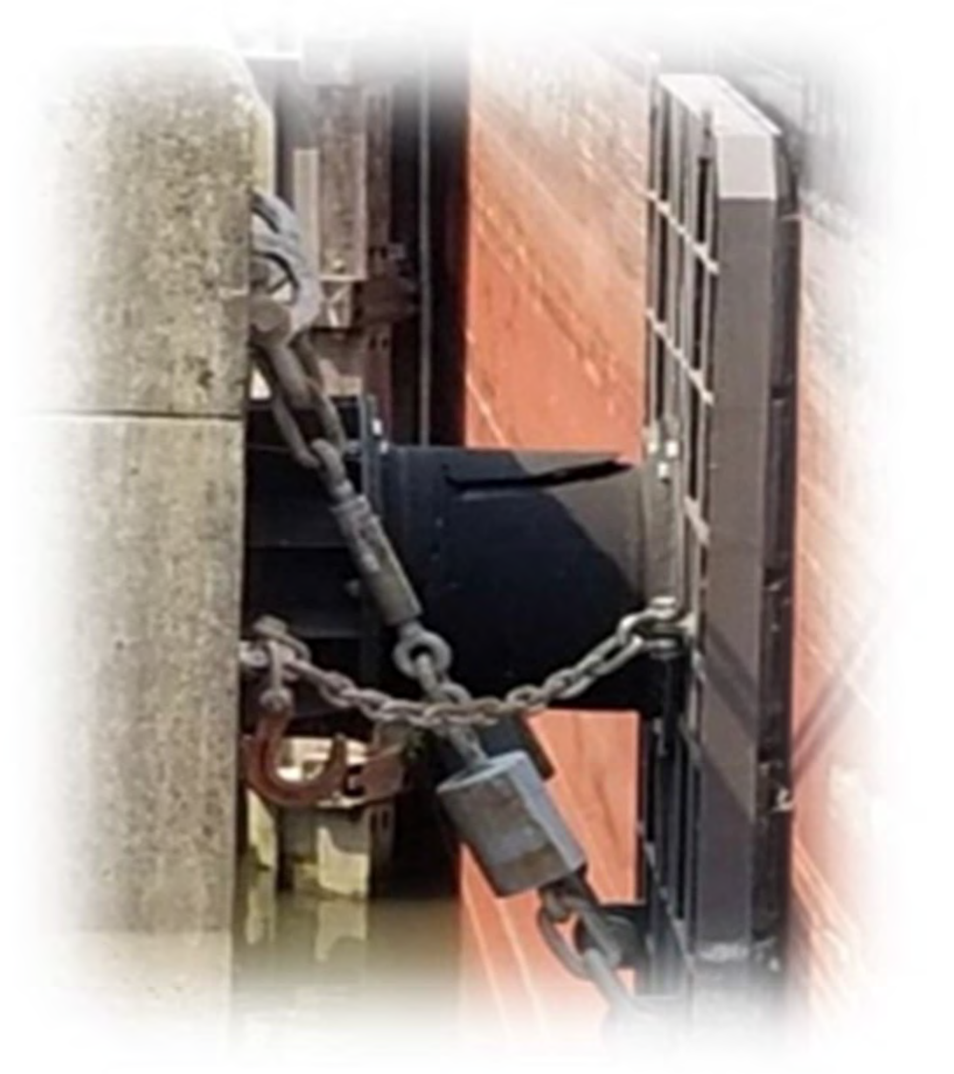
$$R_{f,c} = R_{base}\ C_{v,c}\ C_{t,c}\ C_{ang,c}$$

Characteristic Performance

Fenders Under Moored Conditions

- Fender systems designed for berthing must be evaluated for **mooring suitability**, especially for **lean-on loads**.
- Include waves, wind, currents, passing vessels, and extreme weather.
- Fenders mounted on flexible dolphins require **dynamic response analysis**.

Evaluating how the fender behaves under **time-varying loads**



Fenders Under Moored Conditions

- Need to ensure that peak fender reactions does not exceed vessel hull pressure criteria.
- **Non-Linear** fender behaviour impacts performance of fender under **cyclic loading**.
- Constant loads may cause rubber fenders to deform or buckle below design force.
- If mooring analysis drives the fender design, a sensitivity analysis is recommended to identify if a **different fender system** is required.

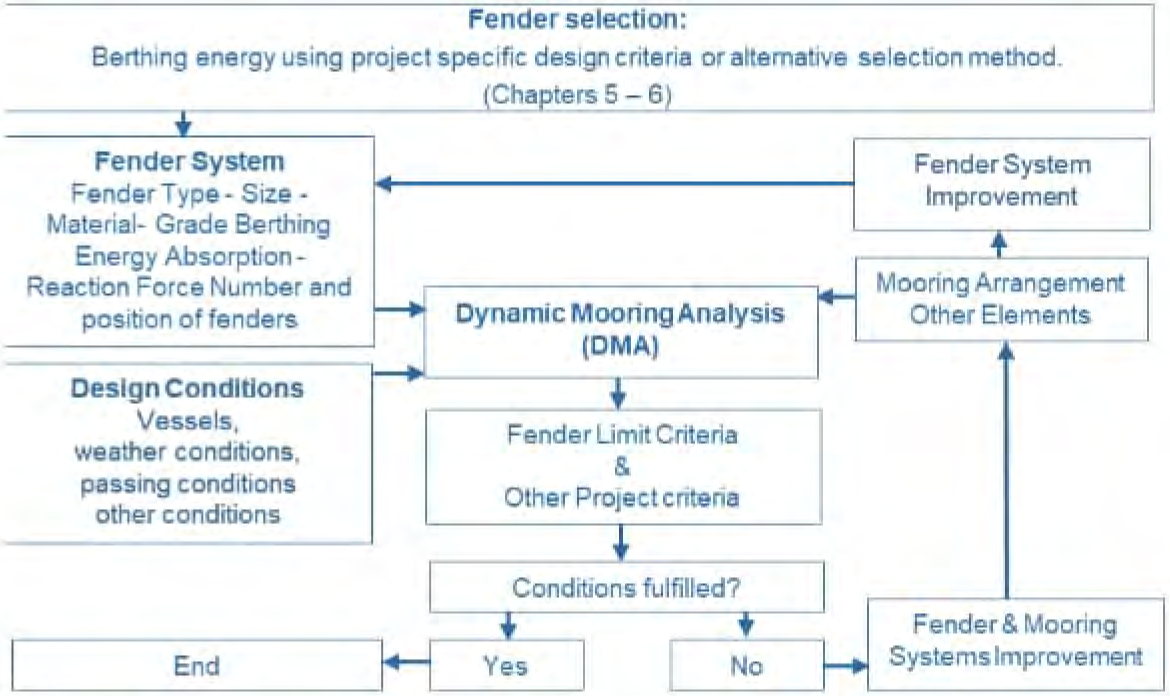


Figure 7.1: Fender design flow chart for moored conditions

HP0

Ship-to-Ship Berthing

- STS berthing refers to the process where two vessels come alongside each other and make contact - typically for transferring cargo, personnel, or supplies.
- Fenders are placed between the two hulls to absorb energy and prevent damage during contact.
- The fender system must account for the combined mass, relative motion, and hull geometry of both vessels.

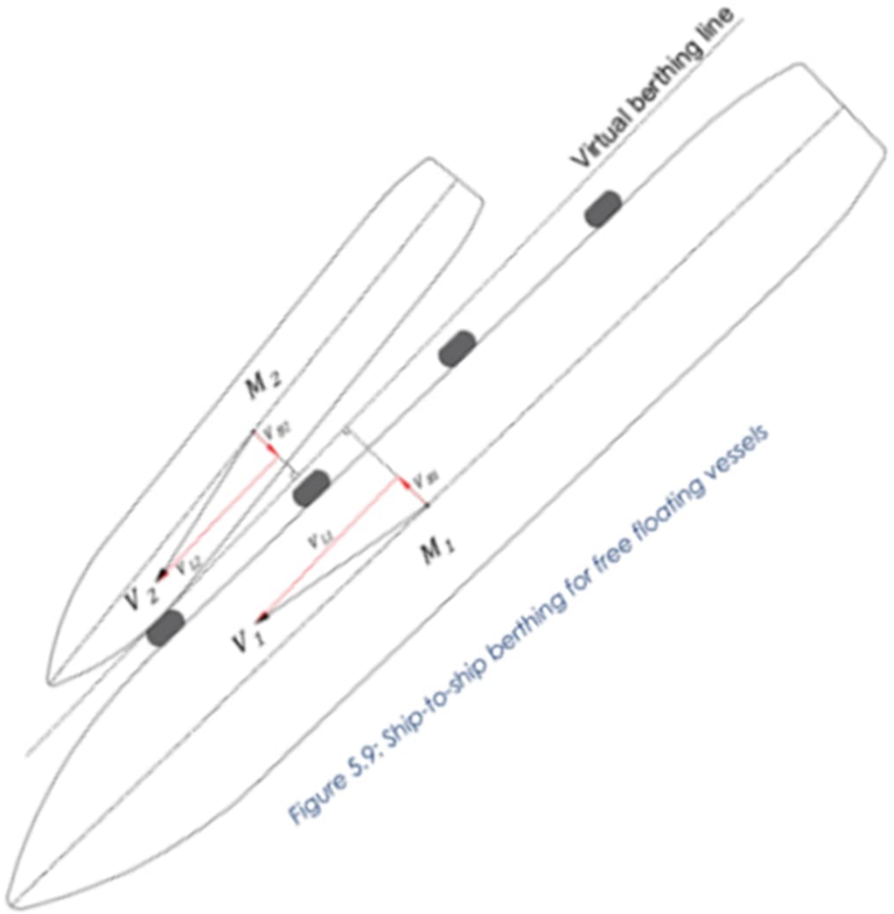


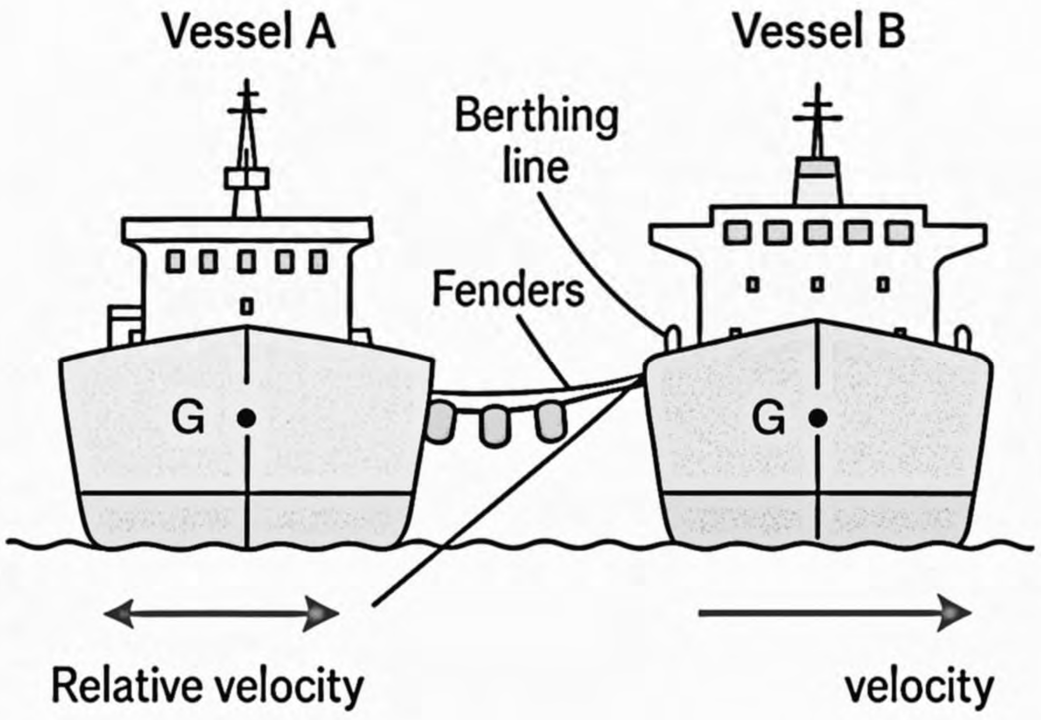
Figure 5.9: Ship-to-ship berthing for free floating vessels

HP0 [@Singh, Harvinder] These two slides provide a very general information of the STS berthing but NOT anything given in the WG211 report. I believe we should add the content provided in the report. I will add modify these slides (including adding if any) tomorrow, if that is ok with you!
Panchumarthi, Hari, 2025-07-29T10:41:30.162

0 0 Sure - please feel free to add/change content. I am considering cutting some slides with basic content at the start as most present tomorrow knows basic fender principals.
Singh, Harvinder, 2025-07-29T11:41:59.486

Ship-to-Ship Berthing

- Berthing energy is based on the relative velocity and mass (including added mass) of both vessels.
- The fender system must be robust enough to handle dynamic loads from two moving bodies.
- Developed primarily for tankers, but applicable to similar vessel types
- STS vs. Fixed Berthing
  - STS velocities are generally higher than fixed berth operations
  - Must account for both vessel masses (real + added mass)



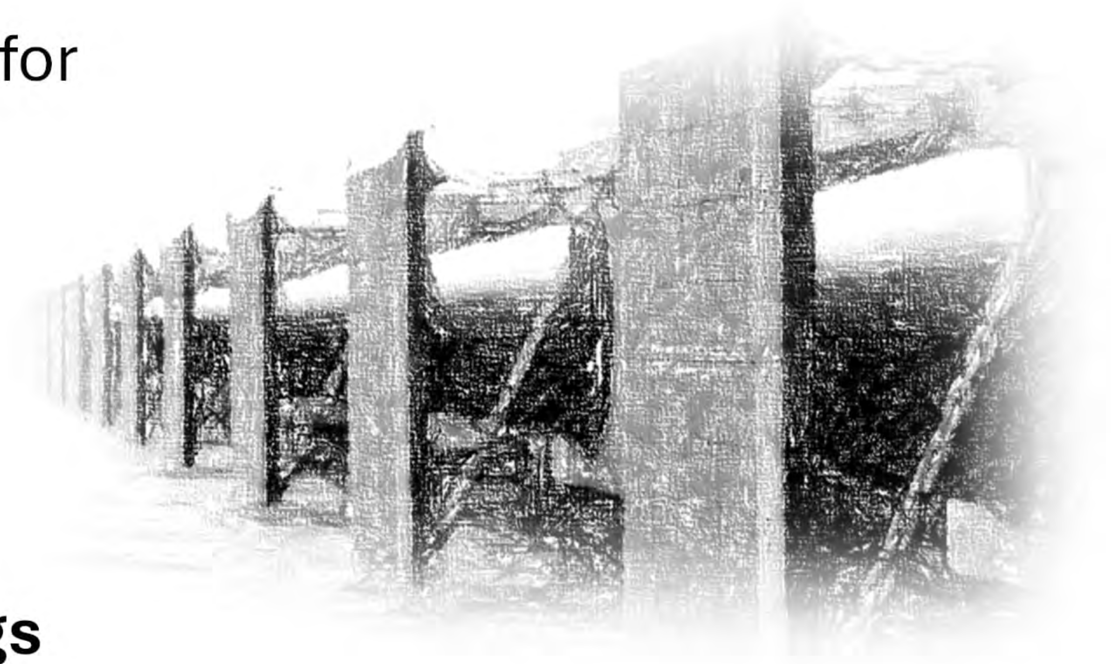
Fender System Component Design

- **Integrated Design Approach** - fender panels, chains, UHMW-PE pads, and fixings must be designed as part of the overall system.
- **Structural Compatibility** - Berth configuration must support all fender components.
- Poor component design or structural mismatch can lead to **reduced durability** or system failure.

Fender System Component Design: Panels

Key Considerations for Designers:

- Ensure **proper contact** surface and height for tides and vessel profiles
- Account for uniform, **line, and point loads**
- Define panel size, structure, welds, and corrosion protection
- Match berth structure to fender system components
- Vessel contact varies: **flat hulls vs. beltings**
- Belting can cause **high-impact loads**—design accordingly



Fender System Component Design: Panels

Panel Size & Position

Panel Width

1. Sufficient contact area to limit hull pressure
2. Accommodate rubber unit and chain connections
3. Consider transport limits and project-specific width requirements

Panel Height

1. Cover full tidal range and vessel draught variations
2. Prevent belting from riding over or under the panel
3. Allow for wave effects and vessel movement

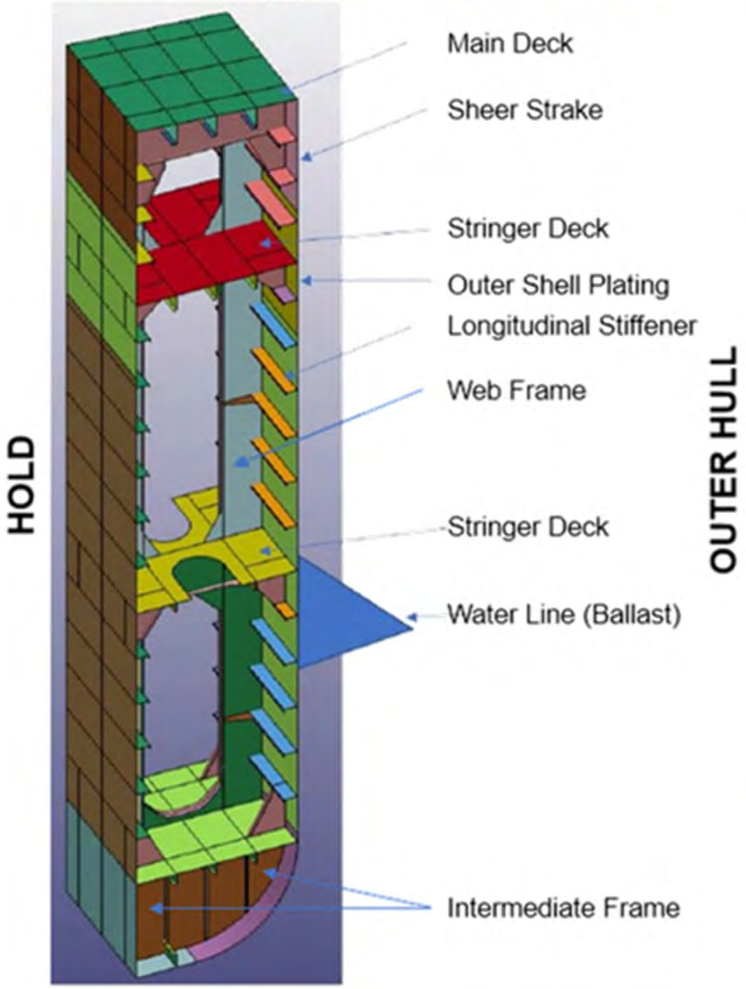
Positioning

1. Align top and bottom panel levels with vessel freeboard and berth structure
2. Avoid interference with mooring lines and vessel ramps

Structural Integration

1. Match panel size with rubber unit dimensions
2. Use multiple rubber units if needed for taller panels
3. Apply engineering judgment for proportional design

Fender System Component Design: Panels



- Transfer of fender loads to the structure of the vessel must not exceed yield stress in the hull plating or stiffeners.
- WG211provides information about typical spacing for stiffeners, frames, etc.
- Designers should obtain vessel-specific permissible hull pressure limits to size fender panels accurately
- In absence of vessel data, use Table 6-6 for typical hull pressure values, which include Classification Society safety factors.
- For naval/military vessels, consult naval architects for precise hull pressure criteria.

Type of vessel	Maximum ultimate hull pressure $(P_{hull,d})$ [1] (kN/m²)	Maximum ultimate fender reaction force $(R_{f,lim})$ (kN)
General Cargo		
≤ 20,000 DWT	500	NK [6]
> 20,000 DWT	400	NK [6]
Bulk Carriers		
≤ 60,000 DWT	200	2,200 [7]
> 60,000 DWT	320	3,800 [7]
Container		
Panamax and smaller	400	1,500 [7]
Neo/post Panamax and larger	200	5,600 [7]
Tankers (see WG 153)		
≤ 60,000 DWT	300	1,800 [7]
> 60,000 DWT	200	NK [6]
Gas carriers (LPG & LNG)	200	NK [6]
Cruise		
≤ 20,000 DWT	400	NK [6]
< 60,000 DWT	300	NK [6]
100,000 DWT	200	NK [6]
Passenger Ferries and RoRo		
RoRo (belting)	Refer Notes 3, 4 and 5 below	NK [6]
RoRo (no belting)	Refer to equivalent size of Cruise Vessel	NK [6]
Passenger (belting)	Refer Notes 3, 4 and 5 below	NK [6]
Passenger (no belting)	Refer to equivalent size of Cruise Vessel	NK [6]
SWATH (double hull vessels)	Refer Note 5 below	NK [6]

NOTES:

1. *The maximum hull pressure values above include for the deduction of factors often used by Classification Societies and can be considered as calculated pressures for semi-probabilistic analysis, associated with non-failure conditions. These values can be considered to act independently to each contact area, with the exceptions as noted in points 2, 3 and 4 below.*
2. *Where fenders are located adjacent to each other (e.g. a vertical or horizontal separation that causes each fender to act in combination with the adjacent fender) and are considered to share the absorption of the vessel berthing energy, the designer may need to consider the forces acting on the hull from these fenders as a group to ensure that the maximum ultimate hull pressure or maximum ultimate fender reaction force capacity is not exceeded.*
3. *Car carriers, RoRo, ferries, cruise, fishing boats, barges and some auxiliary vessels with small displacements, often include one or more belting lines located at different levels on the vessel hull. Refer to section 6.4.8 for more information. These beltings are typically rectangular, trapezoidal or circular in section, protruding approximately 20 to 40 cm from the vessel hull. The designer should check that the magnitude, position and direction of all loads generated by the presence of the belting can be accommodated by the vessel hull structure/plating/belting and the fender system itself. The geometric profiles of the fender panel may need to be refined to accommodate and prevent double hull contact at various states of the tide.*
4. *The typical maximum permitted loads on beltings for vessels with steel hulls is usually between 2,500 and 5,000 kN/m. However, it is recommended that specific information on the structural capacity of the belting is obtained to verify that the forces generated by the fender system can be accommodated. For line loads not on beltings 1000-1500 kN/m is often used. These are empirical numbers that have not been verified.*
5. *Some fast ferries, as well as catamarans, especially if they have aluminium hulls, are not capable of accommodating any kind of direct impact load onto the bottom sections of the hull. In such cases, unless they have special designed belting, the designer will need to ensure that the berthing load impact area is located at a strengthened area of the vessel, independent of the water level.*
6. *'NK' (not known) means that these values have not been calculated by (Berendsen E. A., 2022)or WG 211.*
7. *The numbers are based on (Berendsen E. A., 2022) and are derived from specific vessels. The designer should verify if design vessel and calculated vessel indeed match.*

Table 6-6: Typical values of hull pressure capacity

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Important

Thank You

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Navigating through PIANC Fender Guidelines (WG211)

Session 2: Risk Management

Harvinder Singh
Principal Engineer, Jacobs

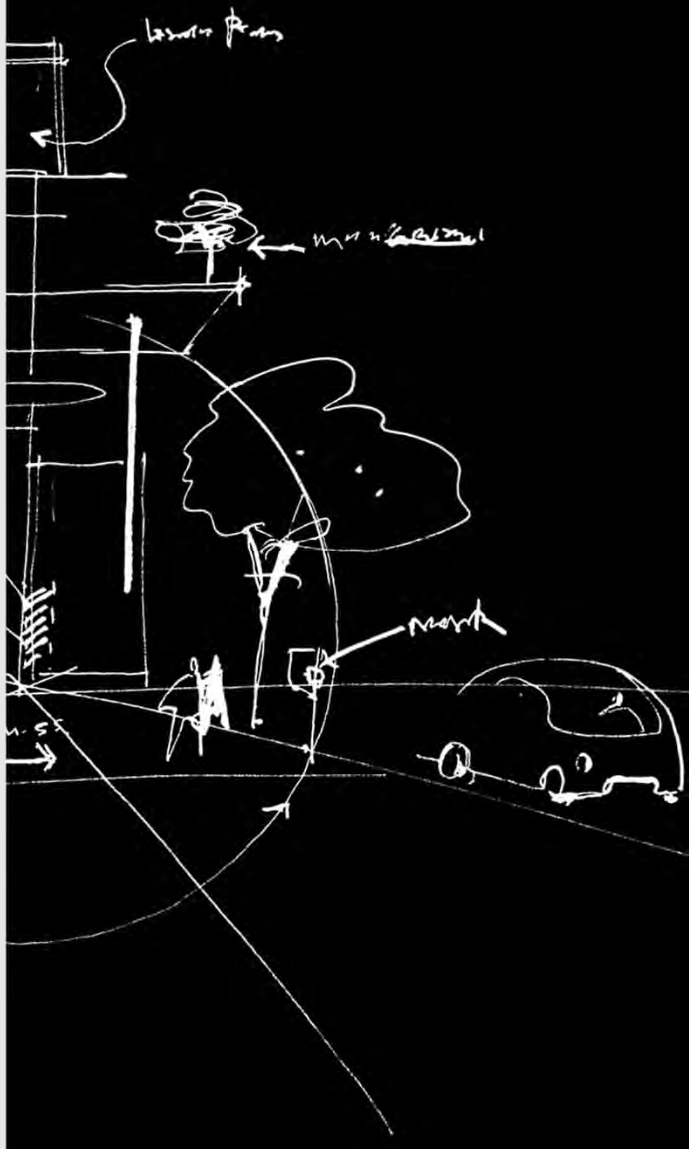
Program

Responsibilities between owner/designer and manufacturer

→ Importance of testing and break in cycle

→ Warranty, product liability of Fender Design

→ Sustainability of fenders



Responsibilities Between Owner/designer and Manufacturer

Owner/Designer Responsibilities

- **Define Project Requirements**
  - Provide site-specific data: vessels, berthing velocities, tidal variations, environmental conditions.
  - Specify performance criteria: energy absorption, reaction force, durability, and safety margins.
- **Fender System Integration**
  - Ensure the fender system is integrated into the overall structure.
  - Consider multiple contact points, angular berthing, and realistic berthing scenarios.
- **Develop Specification**
  - Prepare specifications for procurement.
  - Include testing requirements, installation guidelines, and maintenance expectations.
- **Review and Approval**
  - Evaluate manufacturer proposals and test results.
  - Approve final design and materials before production.

Responsibilities Between Owner/designer and Manufacturer

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- **Review and Approval**
  - Evaluate manufacturer proposals and test results.
  - Approve final design and materials before production.

Manufacturer Responsibilities

- **Design Compliance**
  - Develop fender systems that meet the specified performance and site conditions.
  - Validated design and material properties.
- **Testing and Certification**
  - Conduct type approval testing and factory acceptance testing as required.
  - Provide test reports, certificates, and quality assurance documentation.
- **Manufacturing Quality**
  - Maintain consistent production quality.
  - Use approved materials as shown in design catalogue.
- **Support and Documentation**
  - Supply installation instructions, maintenance manuals, and warranty terms.
  - Offer technical support during installation and commissioning.

Responsibilities Between Owner/designer and Manufacturer

<u>Shared Responsibilities</u>

- **Communication**: Maintain open dialogue to resolve design or performance issues.
- **Risk Management**: Collaborate to address safety, durability, and lifecycle cost concerns.
- **Compliance**: Ensure all work aligns with **PIANC WG 211** and relevant international standards.

Fender System Information	Purchaser (designer, contractor, end user, port authority)	Supplier (contractor, manufacturer)	Chapter
General port and quay information	X		-
Water levels, depth and met-ocean conditions	X		-
Fender system selection	X	X	2, 0
Design vessel information such as displacement, draught, length, beam, hull characteristics, etc.	X		0
Consequence class and design life	X		4.6
Vessel berthing and navigation consideration, **berthing velocity** and angle, tug assisted or not, etc.	X		5
Manufacturing, durability and quality requirements	X		0
Testing requirements	X		0
Additional design specification notes (optional)	X		-
Preliminary design (optional)	X		-
Final design including rubber fender properties		X	-
Installation, maintenance and storage manuals		X	0
Recycling, rubber sourcing, carbon footprint, etc. note	X	X	0
Approval of final design criteria	X		-

Table 13-1: Required fender system design information

Importance of Testing and Break in Cycle

<u>Asset Owner's Role in Fender Testing</u>

- Specify Testing Requirements for all fender types - % performance testing, durability testing, **break-in cycles**.
- Testing must **validate catalogue performance** data and material quality to verify manufacturer catalogue values.
- Witness Critical Tests
  - Allow for **third-party or purchaser-witnessed** testing using independent equipment.
  - **Minimises risk** of biased or inaccurate test results.
  - Engage reputable, third parties with proven expertise to reduces liability and enhances confidence in test outcomes.
  - Direct involvement reduces **risk of non-compliance or underperformance**

Importance of Testing and Break in Cycle

<u>Asset Owner’s Role in Fender Testing</u>

- Testing not limited to rubber component – panels, chains, pneumatic & foam fenders etc.
- Why is documentation & traceability important??
  - Mitigates risk of substandard or non-compliant materials being used.
  - Prevent changes in production facilities to avoid variability in product quality.
  - Reduces risk of performance deviation due to unverified material sources.
  - Proper testing prevents premature failure and costly downtime
  - Supports informed procurement and long-term asset reliability

Warranty, Product Liability of Fender Design

Key Specification Requirements are:

- **Warranty Period** must be clearly defined based on expected fender performance and lifecycle.
- Design **Specific Considerations** include vessel type & berthing frequency
- Design **Vessel Characteristics** such as vessels with belting or high energy absorption needs require tailored fender systems.
- **Environmental factors -** tides, currents, sediment affect fender durability and performance.
- Include details on testing **re-testing** if **performance standards** are NOT met
- Compensation for damage due to defective or fraudulent materials

Warranty, Product Liability of Fender Design

Risks & Impacts of Poor Fender Specification:

Potential Risks:

- Underspecified Warranty → Disputes over performance failures
- Inadequate Insurance → Financial exposure from accidents or damage
- Substandard Materials → Reduced energy absorption, safety hazards
- Design Mismatch → Fender overload or premature failure

Warranty, Product Liability of Fender Design

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Potential Risks:

- Underspecified Warranty → Disputes over performance failures
- Inadequate Insurance → Financial exposure from accidents or damage
- Substandard Materials → Reduced energy absorption, safety hazards
- Design Mismatch → Fender overload or premature failure

Impacts:

- Operational Disruption→ Unsafe berthing, vessel delays
- Increased Lifecycle Costs: Frequent repairs or replacements
- Legal & Reputational Damage: Claims from shipping lines or port authorities

Sustainability of Fenders

- Sustainability is a growing priority in maritime infrastructure.
- It's a growing focus in the last decade and has a priority within PIANC
- Increasing number of ports require sustainable design in all new investments
- Evaluate the full life cycle of fender systems:
  - Material sourcing
  - Manufacturing impacts
  - Operational durability
  - End-of-life recyclability

Challenges in Sustainable Disposal of Old Fenders

- Expensive $$$$$
- Existing rubber recycling systems are designed for thin rubber products - tyres, conveyor belts
- Large fenders with steel inserts are difficult to process and grind into reusable material.

Current Disposal Practices:

- Many ports store old fenders indefinitely due to lack of alternatives.
- Some fenders are disposed of via landfill or burned as Tyre-Derived Fuel (TDF).

So, there's a need for innovation

Sustainability of Fenders

A Sustainable Future for Fender Systems

- Sustainability is increasingly important in ports and manufacturing, including rubber-based products like fenders.
- Recycling and carbon footprint mapping remain key hurdles for fender manufacturers.
- Designers, manufacturers, end users, and stakeholders must work together to develop and implement sustainable solutions.
- All parties involved in fender system selection, design, and production should contribute to improving sustainability.
- Despite limitations, smarter material choices and engineering practices can already reduce environmental impact.

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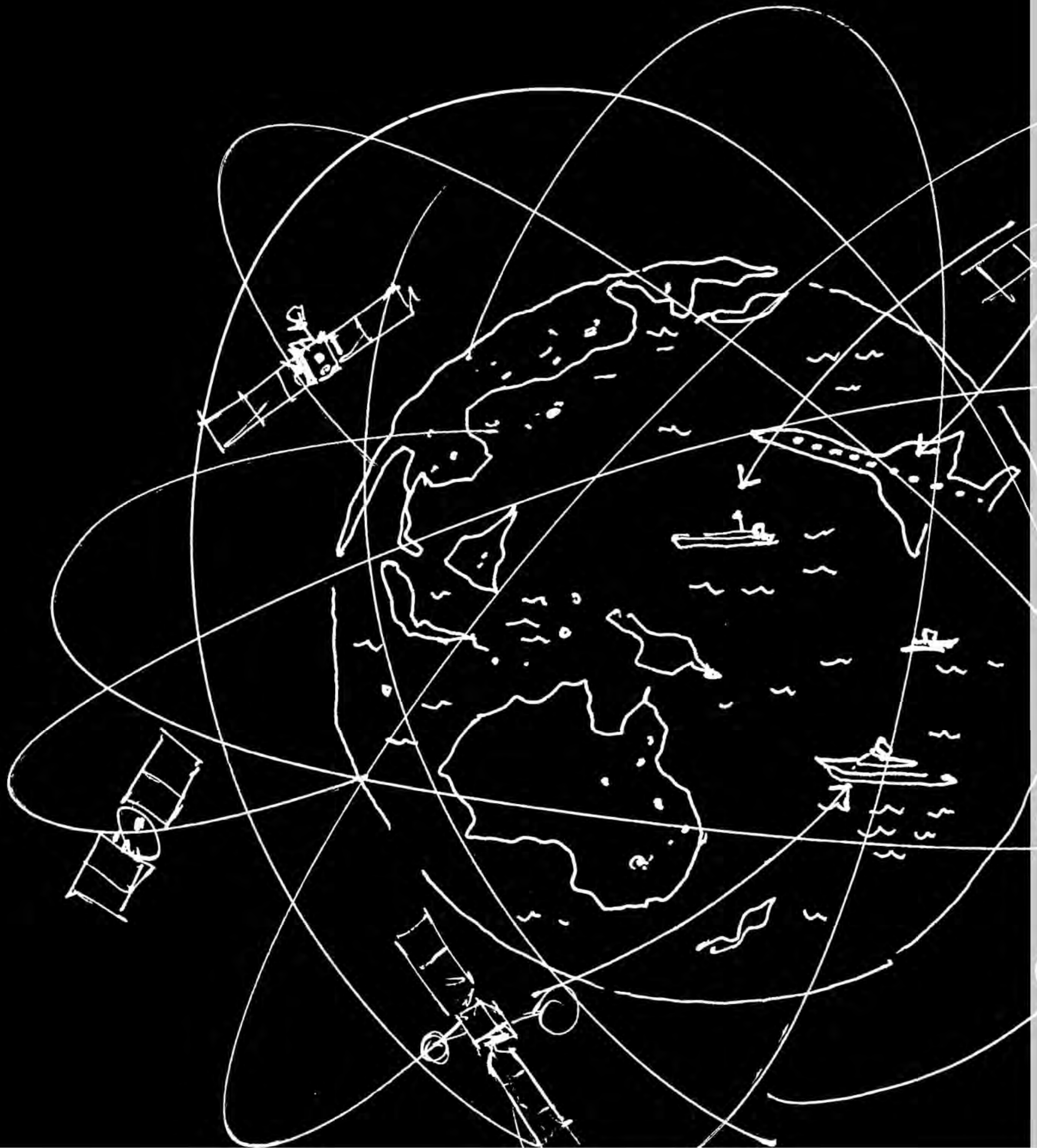

Important

Thank You

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SESSION 3

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PIANC AU-NZ
The Australian Northern Chapter of the World Association for Waterborne Transport Infrastructure
WORKSHOP
NAVIGATING THROUGH PIANC FENDER GUIDELINES 2024 (WG211) FOR DESIGNERS AND ASSET OWNERS
WED 30 JUL 2025 | 12:30PM - 5:30PM
ENGINEERS AUSTRALIA
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BRISBANE QLD
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NON-MEMBERS $50
STUDENTS FREE

Session 3 – Asset Owner Focus

Dr. Sam Mazaheri

Principal Engineer, Dalrymple Bay Terminal

Director, Beta International Associates Pty Ltd

With a strong focus on practical, fit-for-purpose engineering and innovation, Sam brings deep insights into fender system design and performance, supporting the delivery of sustainable, safe, and long-life port infrastructure.

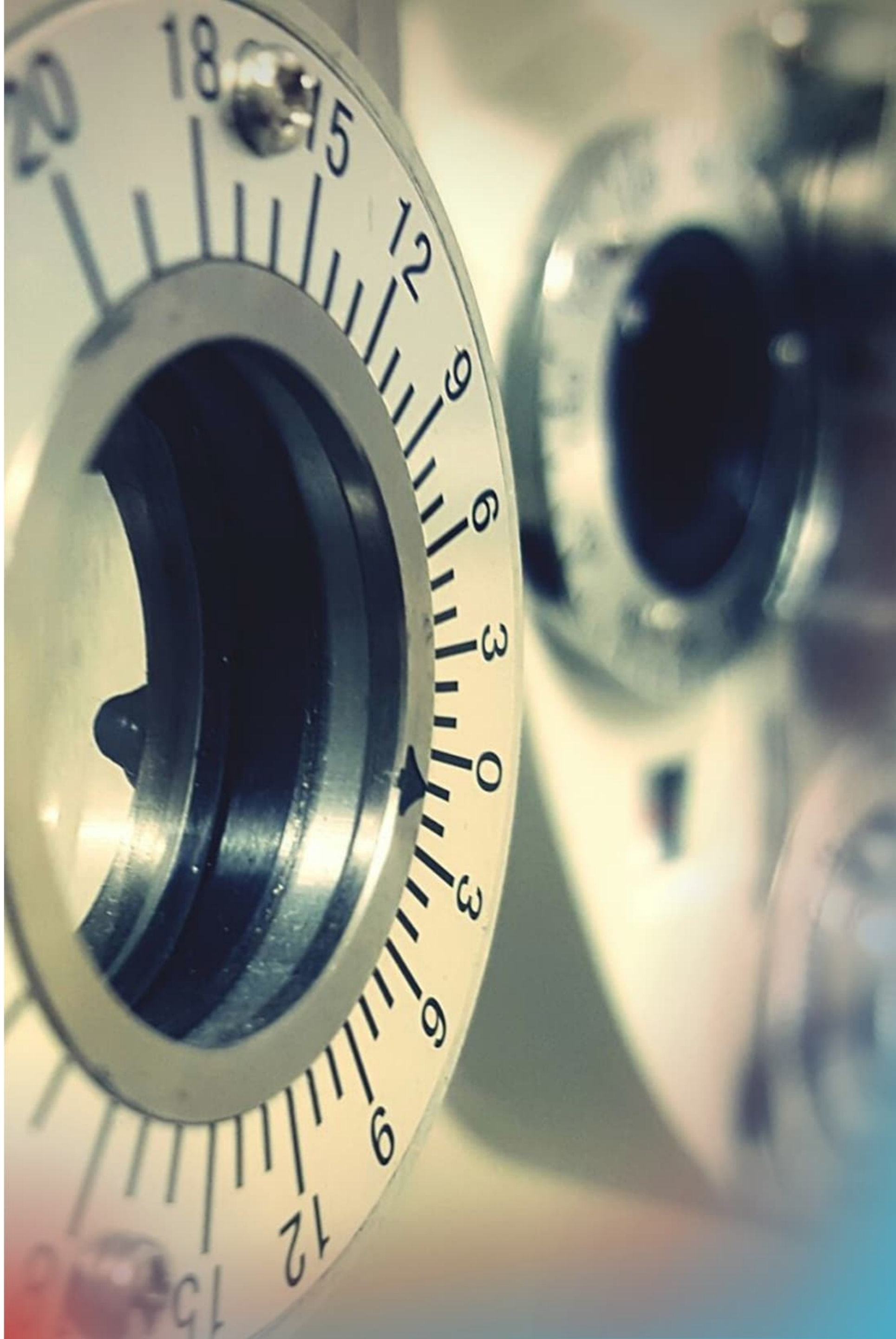
Dr. Sam Mazaheri is a Chartered Engineer in civil, structural, and asset management disciplines, with over 30 years of experience in the design, assessment, and maintenance of maritime and port infrastructure. As a Principal Engineer at Dalrymple Bay Terminal, he is responsible for the engineering performance and resilience of one of the Australia's most critical bulk export facilities.

He currently serves as the QLD and NT Chair of PIANC AU–NZ and contributes to several national and international technical working groups, including PIANC WG211 on fender systems. His applied research spans climate impact assessments, infrastructure resilience, and digital twin technologies, with recent involvement in the SmartCrete CRC initiative.

Fenders Through Ports and Terminal Lens – Navigating WG211

PIANC WG211 | Session 3 – Asset Owner Lens

Dr. Sam Mazaheri, Principal Structural and Maritime Integrity Engineer




PIANC
The World Association for Waterborne Transport Infrastructure
PIANC FENDER GUIDELINES 2024
Com Working Group R


rangement - Fender.jpg

Introduction

WG33 – Generic, Prescriptive

Fixed Velocities
Limited Input

WG211 – Site Specific, Risk Based

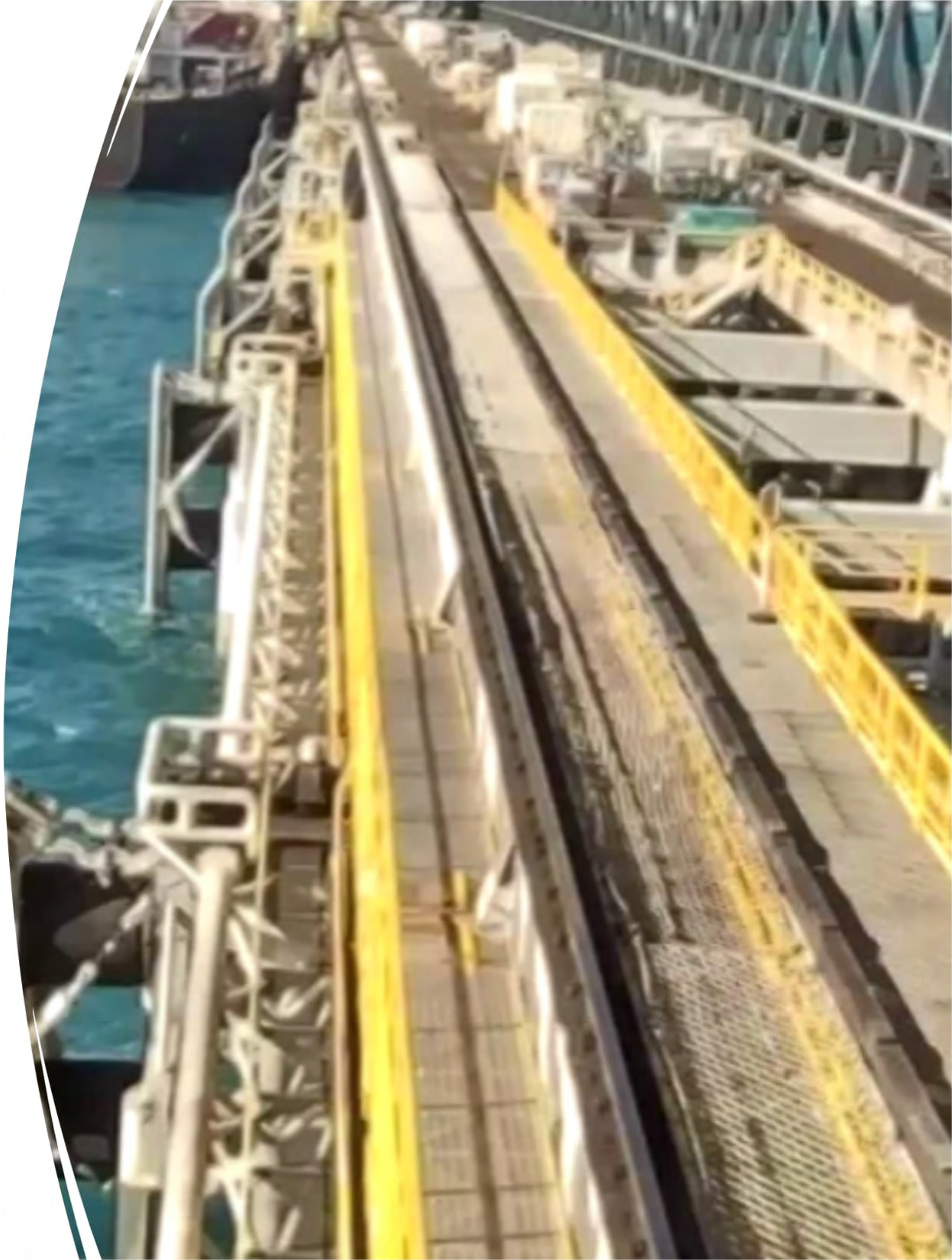
Pilot Input
Berthing Log

Role of fenders in port/terminal safety and asset protection.

WG211 is a major shift from WG33: deeper operator involvement needed.

Key Changes in WG211

- WG211 is a complete overhaul – not just a revision.
- Focus on site-specific data, multiple fender contacts, realistic berthing velocities.
- Design safety is now built into the fender – not left to the structure.



Key Differences Between WG33 and WG211

Aspect	WG33	WG211
Approach	Generic, prescriptive	Site-specific, risk-based
Input Assumptions	Fixed vessel sizes and impact energies	Variable vessels, berthing speeds, and angles
Design Flexibility	Limited	High – adapted to local conditions
Stakeholder Involvement	Minimal operator input	Deep operator involvement essential
Risk Consideration	Not explicitly addressed	Central to design process
Multiple Contact Scenarios	Rarely considered	Specifically addressed
Focus	Fender design parameters	Broader system performance and safety

Implications for Asset Owners

- Operators must provide berthing data – not optional anymore.
- New standards for inspection, reliability, and failure definition.
- Failure can occur without visible damage – risk-based asset management is key.

Maintenance & Whole-of-Life (WG211 Approach)

WG211 promotes scheduled inspection and maintenance	• Refer to Chapter 11, Table 11-1: risk-based inspection frequency • Tailored to fender type, location, and criticality
Key considerations in whole-of-life planning	• Degradation over time: rubber fatigue, corrosion, UV, impact wear • Accessibility challenges: underwater or tidal exposure, confined spaces • End-of-life triggers: loss of energy absorption, cracking, hardening, anchor system failure
Adopt emerging technologies	• Drones for aerial inspection and damage capture • Sensors to monitor strain, compression cycles, or impact loads • 3D scanning / photogrammetry for deformation tracking • Enables predictive maintenance and digital twin integration
Asset management integration	• Condition data feeds into CMMS and digital registers • Supports budget forecasting, renewal planning, and audit readiness • Aligned with ISO 55000 asset lifecycle management
Hidden risks (support the image below)	• Visual checks alone may miss internal damage or loss of performance
Emphasises the need for non-destructive and invasive inspections	

Operational Lessons

Examples:

- Poor berthing data = undersized fenders.

- Deferred maintenance = berth shutdown.

- Spec mismatches = contractor issues.

Incorporate WG211 into risk registers and AMPs.

Operator's Role Forward

Provide berthing data and feedback.

Support documentation and inspection routines.

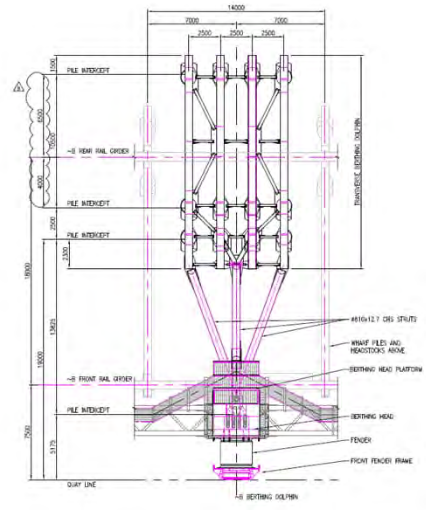
Reject misleading 'PIANC certified' claims – PIANC is not a certifier.

Prepare for transition: WG211 applies after May 2026.

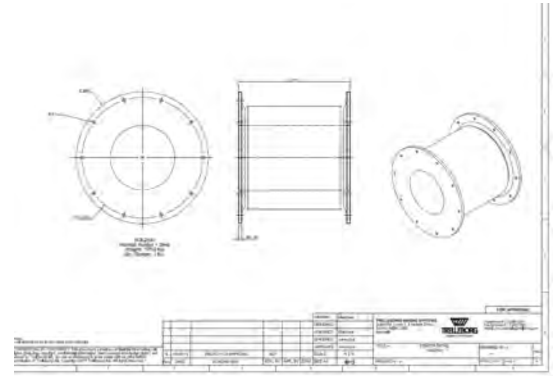
PIANC Certified Fenders and PIANC Type Approval

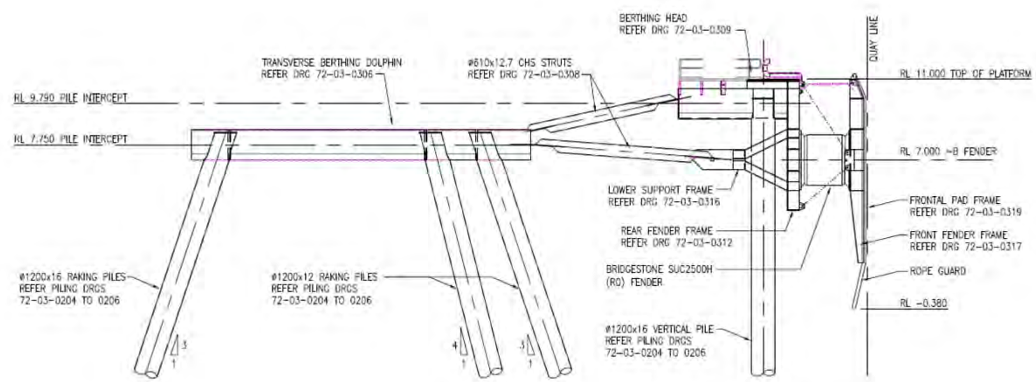
- Material Certification
  - Confirms rubber, steel, and other materials meet required standards.
  - Includes compound testing and ISO-compliant certificates.
- Factory Production Control (FPC)
  - Verifies quality systems (e.g. ISO 9001) and production traceability.
- Type Testing Certification
  - Confirms fender performance (reaction force, energy absorption, angles).
  - Independently tested or witnessed.
- Project-Specific Performance Certification
  - Validates performance under site-specific conditions and risks.
  - May include full-scale or prototype testing.
- Installation Certification
  - Confirms correct installation per design.
  - Includes torque checks, alignment, and survey reports.
- Third-Party / Independent Verification
  - Strongly recommended for critical assets.
  - Covers design, production, and testing.

Example



BERTHING DOLPHIN PLAN
SCALE 1:100





BERTHING DOLPHIN ELEVATION
SCALE 1:100

Example

DOLPHIN SYSTEM DESIGN PARAMETERS:

DESIGN VESSELS:

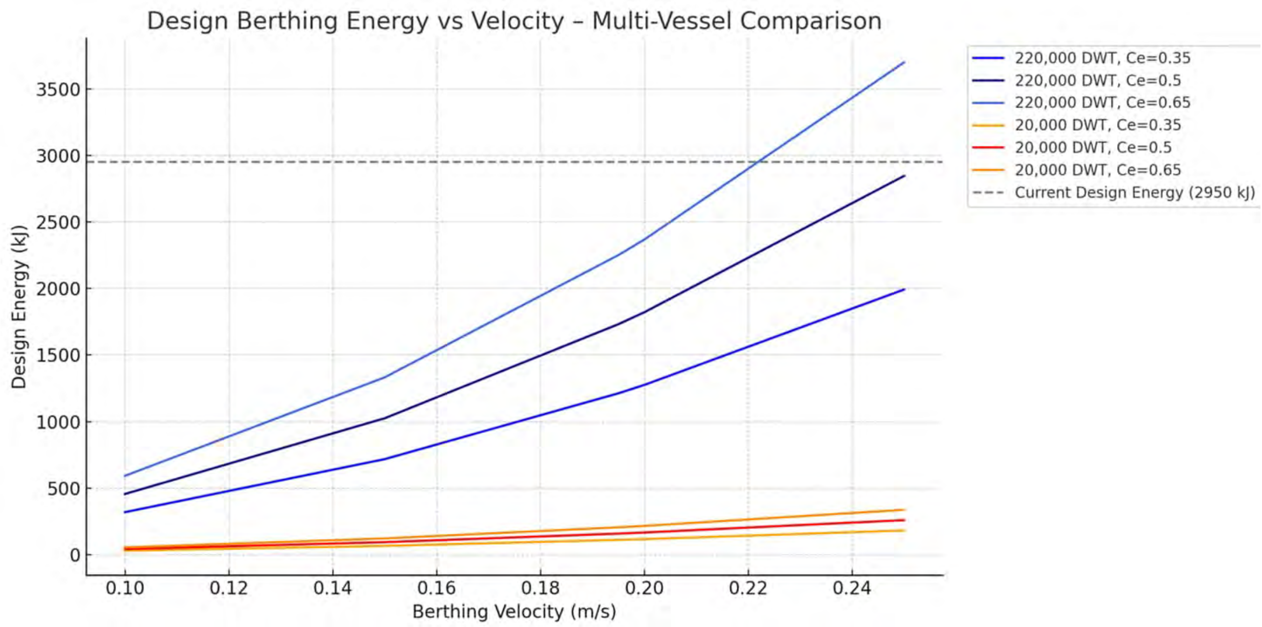
	MINIMUM DESIGN VESSEL	MAXIMUM DESIGN VESSEL
DEAD WEIGHT TONNAGE	20,000 DWT BULK CARRIER	220,000 DWT BULK CARRIER
LENGTH OVERALL	154m	320m
BEAM	21.75m	51m
LADEN DRAFT	9.5m	19m
EMPTY DRAFT	3.0m	4.25m
MOULDED DEPTH	13m	25m
BOW TO HATCH	16m	26m
HATCH LENGTH	106m	242m
STERN TO HATCH	32m	52m
VESSEL LIGHT WEIGHT	20% OF DWT	20% OF DWT

FENDER SYSTEM DESIGN PARAMETERS:

DESIGN PARAMETER	VALUE
MINIMUM DESIGN ENERGY ABSORPTION, E_D	2950kJ
MAXIMUM DESIGN REACTION, R_D	3350kN
MAXIMUM BERTHING ANGLE	3°
MAXIMUM ROLL ANGLE	0°
LADEN CONDITION	LIGHT BALLAST TO 67% LADEN
BERTHING CONFIGURATION	QUARTER-POINT
BERTHING VELOCITY	195mm/s

MOORING HOOK DESIGN PARAMETERS: DOLPHINS DESIGNED FOR HOOK CAPACITIES AS SHOWN

Desing Berthing Energy vs Velocity



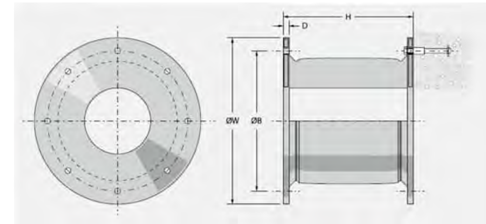
Key Observations:

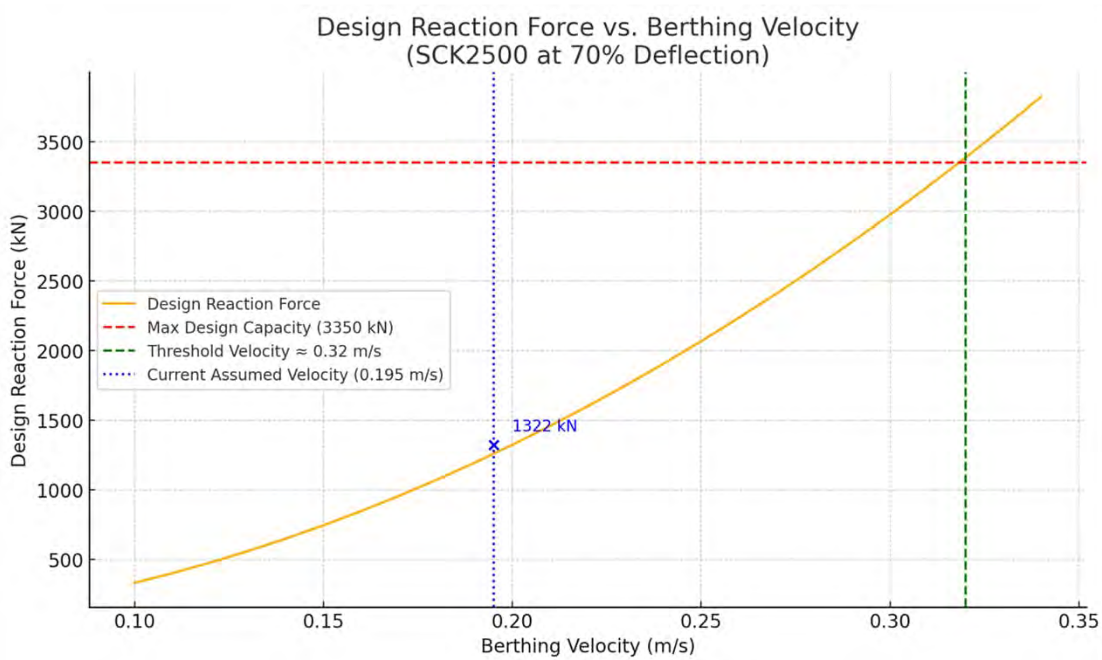
- The current design energy of 2950 kJ is shown as a dashed grey line.
- For typical quarter-point berthing (Ce = 0.5), WG211-calculated energy only approaches 2950 kJ when the velocity exceeds 0.23–0.24 m/s.
- For midship contact (Ce = 0.65), the design energy surpasses 2950 kJ at ~0.21 m/s.
- Bow-only contacts (Ce = 0.35) result in significantly lower energy demand, even at higher velocities.

	H	ØW	ØB	D	ANCHORS / HEAD BOLTS ^	WEIGHT
SCK 2500	2500	2950	2700	65 – 80	10 × M64	10700
SCK 3000	3000	3350	3150	70 – 90	12 × M76	18500

^ Fender anchors / head bolts indicated are based on fenders RDP performance using a particular grade of steel. Please contact our local office for precise size, material and type for different grades of fenders pertaining to the project requirements.

[Units: mm, kg]





- For a 220,000 DWT bulk carrier at 0.195 m/s:
- Assumed design energy: 1732 kJ
- Safety factors applied: γf = 1.1, γmult = 1.05, γR = 1.1
- Results:

  70% Deflection (1.75 m):
  Characteristic Force: 990 kN
  Design Force: 1257 kN

  65% Deflection (1.625 m):
  Characteristic Force: 1066 kN
  Design Force: 1354 kN

Manufacturer Data Report (MDR)

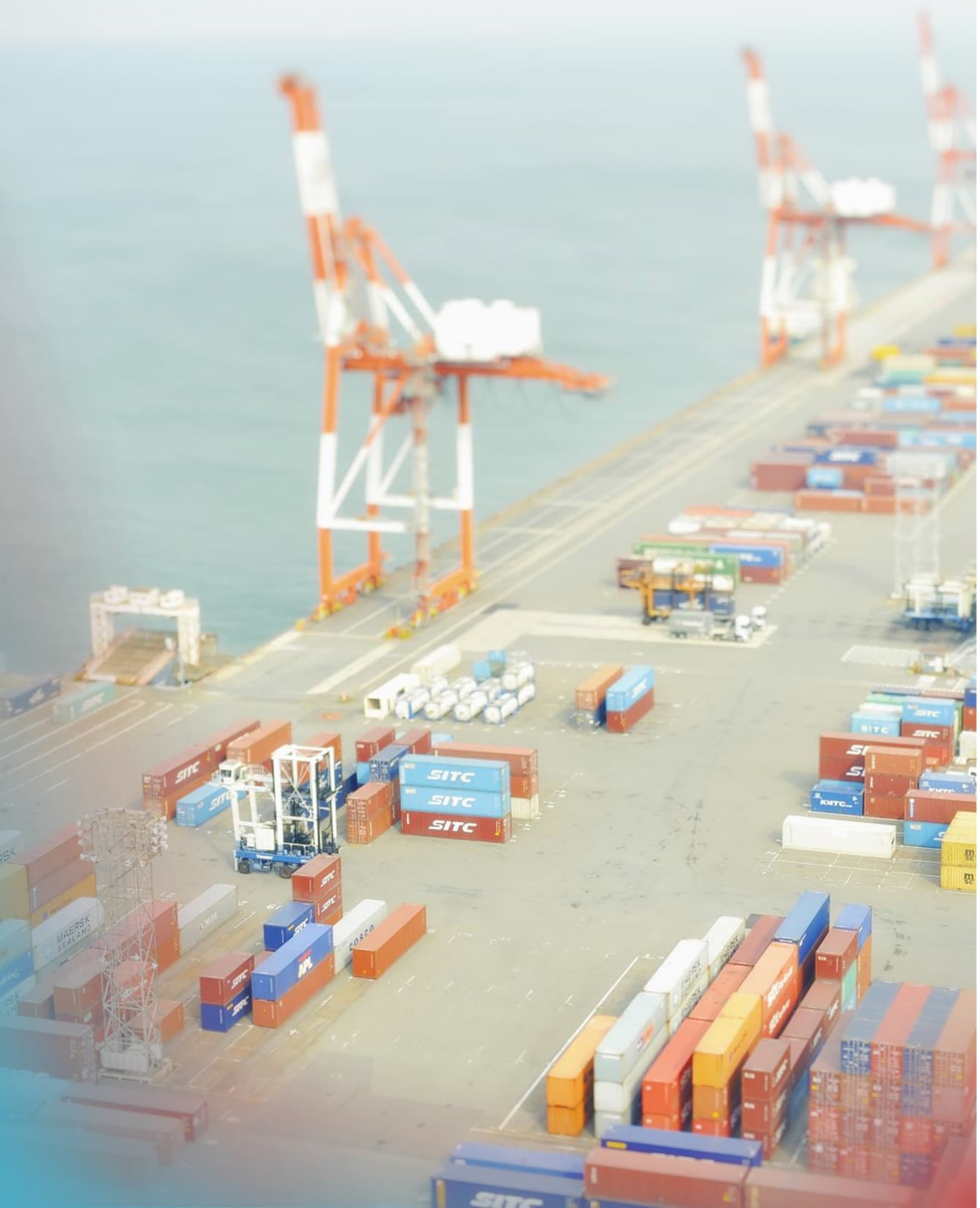
- Rubber Material Test Report
- Fender Compression Test
- Fender Dimensions Check
- Inspection and Test Plan

Inspection and Test Plan

LEGEND	R=Document Review, M=Monitoring, W=Witness Point, H=Holding Point, I = Inspection	TEST LOCATION	
PREPARED BY		DATE	

Item	Activity	Test Method	Vendor Reference Procedure/Controlling Document/Code/Standard	Acceptance Criteria Codes/Standards and Specification	Scope	Vendor´s Verifying Document	Factory - YAN		MoorMarine		Client (Optional)		Third Party (Optional)		Comments/ Remarks
							IP	Signature/ Date	IP	Signature/ Date	IP	Signature/ Date	IP	Signature/ Date	
0	**DOCUMENTATION**														
0.1	Review Purchase Order (PO)	Doc Review	Quotation PO Concession and deviation list (CDL)	In accordance with agreements		PO signed	H		H		H				
0.2	Drawings and Documents Approval	Doc Review	-	Quotation PO Concession and deviation list (CDL) MoM Agreements		Project´s documents with contractor stamp/signature	H		H		H				
1	**RUBBER PROPERTY FOR COMPOUND**														
1.1	Hardness (Shore A Durometer) Hot Air Aging condition (70°C, 96hours)	Lab Testing	ISO 7619-1: 1986	≤ 84° before aging Max. original value +8° after aging	Before/after aging	Test Report	H		R		R				
1.2	Tensile Strength Hot Air Aging condition (70°C, 96hours)	Lab Testing	Before aging: ISO 37: 2005 (Method 1A) After aging: ISO 188: 1998 (Method 1A)	Min 15.7 MPa before aging Not less than 80% of original value after aging	Before/after aging	Test Report	H		R		R				
1.3	Elongation At Break Hot Air Aging condition (70°C, 96hours)	Lab Testing	Before aging: ISO 37: 2005 (Method 1A) After aging: ISO 188: 1998 (Method 1A)	Min 300% before aging Not less than 80% of original value after aging	Before/after aging	Test Report	H		R		R				

Item	Activity	Test Method	Vendor Reference Procedure/Controlling Document/Code/Standard	Acceptance Criteria Codes/Standards and Specification	Scope	Vendor's Verifying Document	Factory - YAN		MoorMarine		Client (Opti	
							IP	Signature/ Date	IP	Signature/ Date	IP	Signa D
1.4	Compression set. (70°C, 22h)	Lab Testing	ISO 815: 1991 Type A	Max 30%	Before/after aging	Test Report	H		R		R	
1.5	Ozone Resistance (50ppm at 20% strain, 40°C, 100 hours (OPTIONAL)	Lab Testing	ISO 1431-1	No crack	Before aging	Test Report	H		R		R	
2	**COMPRESSION TEST OF FENDER**											
2.1	Rubber Performance	Compression test	According to PIANC "Guidelines for the Design of Fender Systems 2002	PIANC 2002	10% of PO quantity	Test Report	I		R		R	
3	**DIMENSION CHECK OF FENDER**											
3.1	Visual & Dimensional Control	Inspection	Project Drawings	Complies with Project Drawings	100% from PO quantities Not considered defects: burring, repair and minor marks.	Vendor Visual & Dimensional Report	I		R		R	
4	**FINAL INSPECTION**											
4.1	Packing Inspection & delivery	Visual Inspection Quantities Protected Marking	PCD-0000-0000-v0_package_shipping_and_storage_procedure	PCD-0000-0000-v0_package_shipping_and_storage_procedure	All material from PO	Packing list	R		R		R	
5	**QUALITY DOSSIER**											
5.1	Compilation of Final Dossier	Doc Review	Vendor's Procedure	Document approved Certificates Reports		Data book	R		R		R	



Thank You

- Let’s work together to implement WG211 consistently across our ports and terminals.
- Questions? Discussion?

TEA BREAK

PIANC AU-NZ
The Australian Northern Chapter of the World Association for Waterborne Transport Infrastructure
A.D. 1885
PIANC
AIPCN
NAVIGARE NECESSE
WORKSHOP
NAVIGATING THROUGH PIANC FENDER GUIDELINES 2024 (WG211) FOR DESIGNERS AND ASSET OWNERS
WED 30 JUL 2025 | 12:30PM - 5:30PM
ENGINEERS AUSTRALIA
LEVEL 9/340 ADELAIDE ST
BRISBANE QLD
MEMBERS $30
NON-MEMBERS $50
STUDENTS FREE

SESSION 4


A.D. 1885
PIANC
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STUDENTS FREE

Session 4 – Manufacturer Lens

James Curl, Regional Director, Marine Fenders APAC

Adam Sellers, General Manager, Marine Fenders Oceania

This session delves into the manufacturer's side of fender systems, guided by PIANC WG211. Participants will learn about the interface between engineering design and manufacturing, covering essential information like drawings and specifications.

We'll examine the production methods for different fender types, including rubber, steel panels, and pneumatic/foam fenders. The discussion will include key testing procedures, factors affecting results, sustainability, and how to specify performance and durability requirements.

James is a Mechanical Engineer with 15 years' experience spanning machine design, manufacturing, project management, and team leadership. For the past decade he has planned, engineered, and delivered complex marine fender systems across the Asia Pacific region. At Trelleborg Marine & Infrastructure, where he oversees Project & Sales offices in SYD, Singapore, Japan, and China.

Adam is a Mechanical Engineer, he oversees all sales, engineering, and project management functions for fendering projects across Australia, New Zealand, and Oceania. Originally from the USA, Adam has been involved in hundreds of marine fender projects across the North American and Australian regions, and his extensive background spans sales, engineering, PM, design, and manufacturing within the marine, consulting, and oil & gas sectors.

Session 4: Manufacturer's Perspective

TRELLEBORG

PIANC AU-NZ WG211 Workshop

Session 4: Manufacturer's Perspective

Trelleborg Group —

A world leader in engineered polymer solutions

Focused **polymer group**

founded **1905**

Annual sales **EUR ~2.97 billion**

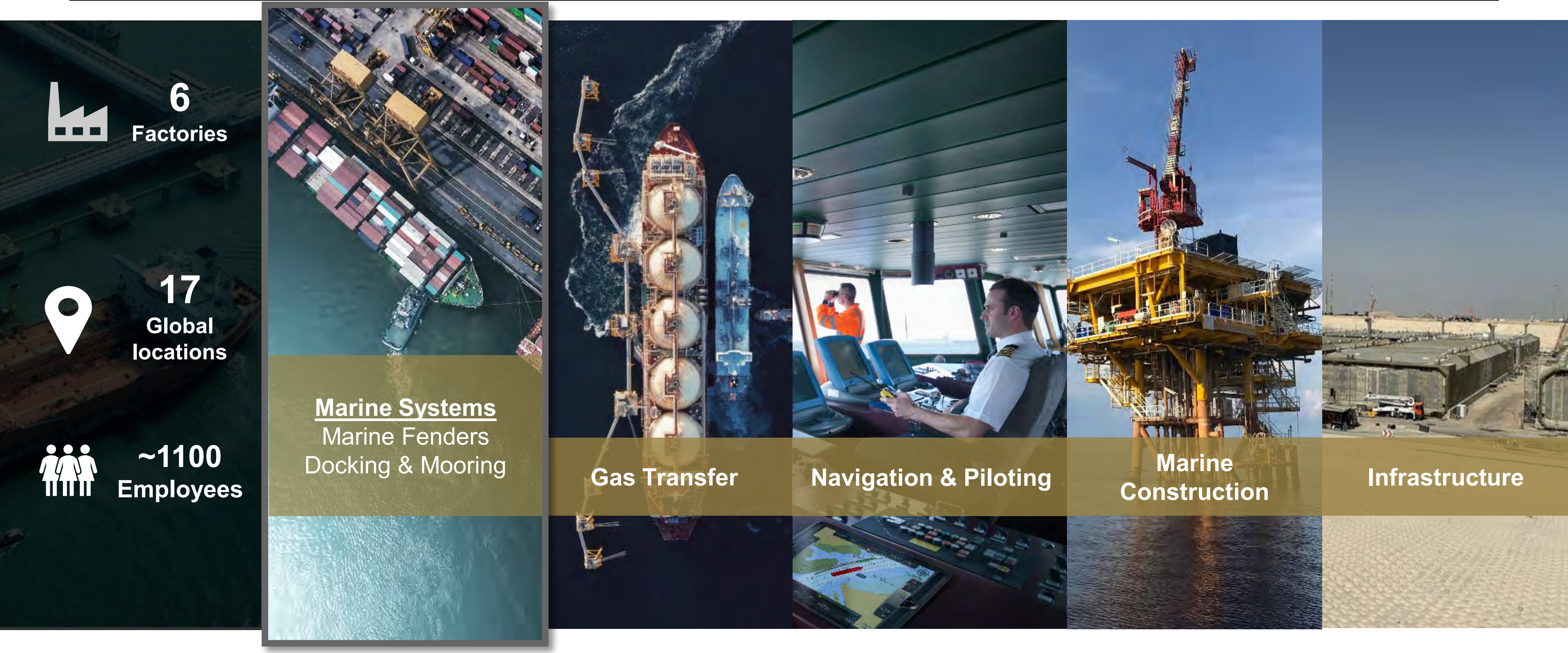
>16,000 employees

40+ countries

~100 manufacturing facilities

Trelleborg Marine & Infrastructure

Business unit overview



6
Factories

17
Global locations

~1100
Employees

Marine Systems
Marine Fenders
Docking & Mooring

Gas Transfer

Navigation & Piloting

Marine Construction

Infrastructure

TRELLEBORG

Trelleborg Marine Systems

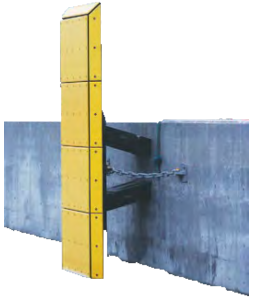
Marine Fenders

Fixed Rubber Fenders

Cone Fender

Cell Fender

Arch | Extruded | Composite Fenders



Unit Type (Leg Fenders)S

Floating Fenders

Pneumatic Fenders

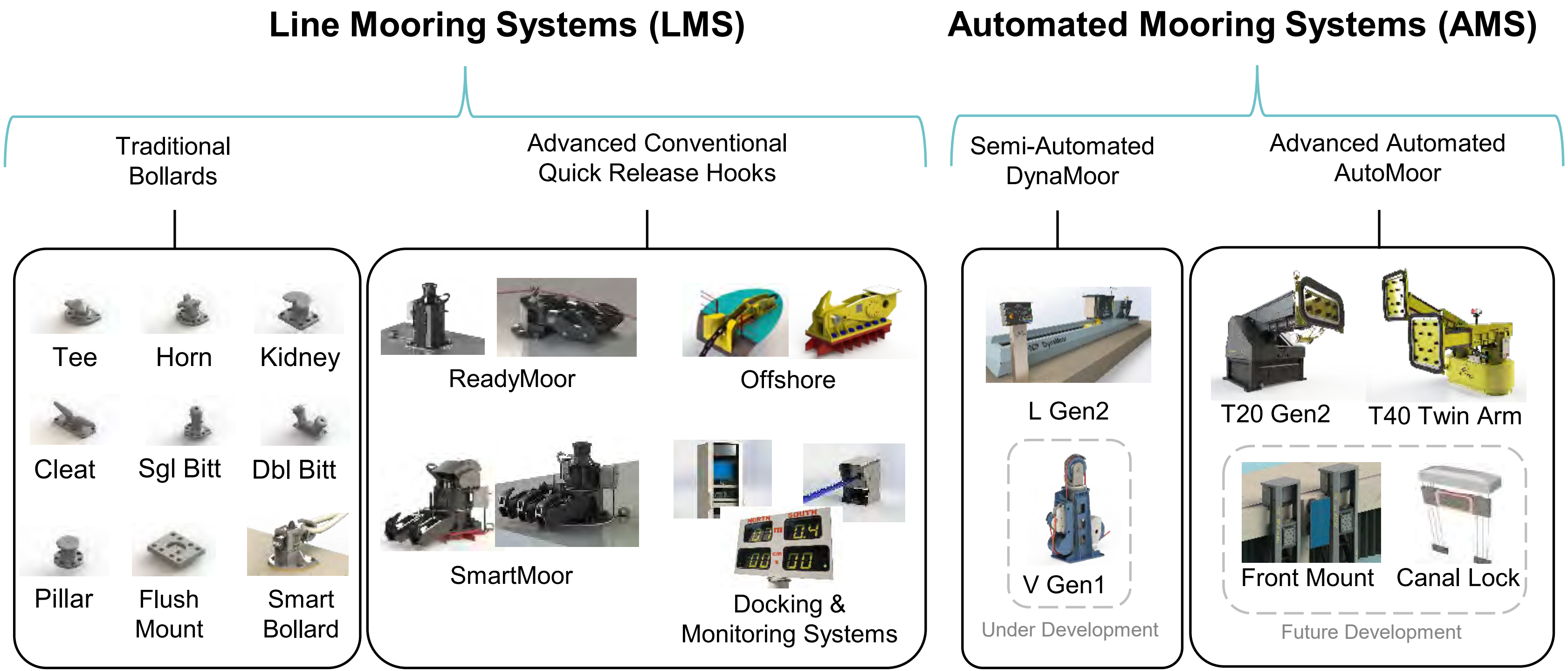
Foam Fenders

Hydro-Pneumatic Fenders

Donut Fenders

Trelleborg Marine Systems

Docking and Mooring



TRELLEBORG

Global Footprint

Trelleborg Marine & Infrastructure

- 4 Production sites
- 13 Sales offices
- 1 Engineering centre (Ahmedabad)
- Ho Chi Minh opening Nov 2025

TRELLEBORG

Interface between Designer & Manufacturer

TRELLEBORG

Interface between Design Engineer & Manufacturer

Fender Design: A Whole System Approach

Application Engineering

- Berthing conditions
- Normal and abnormal berthing energy
- Fender selection & correction factors
- Fender specification

Detailed Engineering

- Size of all fender systems components
- Check load cases and designs
- Calculation and designs drawings

Ensure a long-lasting fender system

Manufacturing and Quality Control

- Ensure fender systems meet specifications, design, international standards, and project requirements.
- Quality & project documentation
- Project management & logistics

Operation and Maintenance

- Installation & commissioning
- Scheduled maintenance
- Fender recycling

Interface between Design Engineer & Manufacturer

WG211: A Whole System Approach

01
Application engineering
Chapters 1 - 7

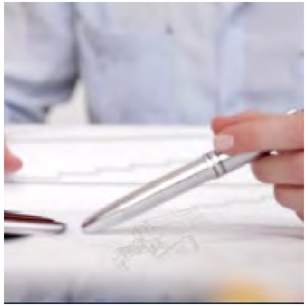
02
Detailed fender system design
Chapter 8

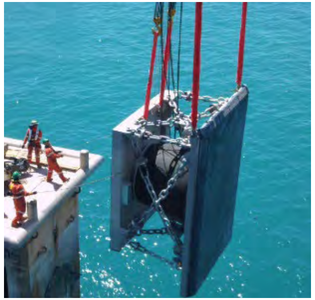
03
Fender production & quality control
Chapter 9 & 10

04
Installation, operations and maintenance
Chapter 11

05
Sustainability and recycling
Chapter 12

Specification (Chapter 13)



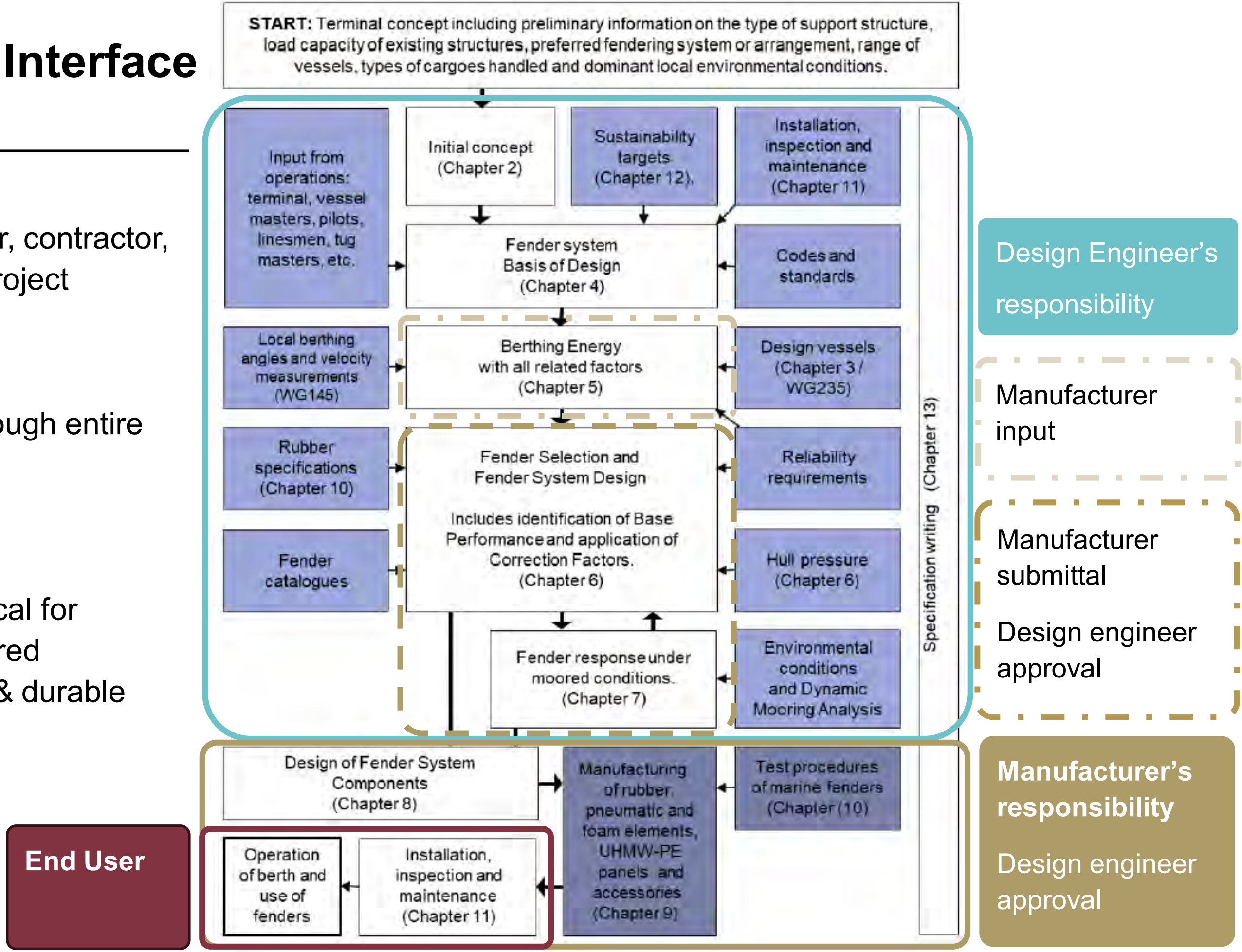


Fender Life Cycle

Designer / Manufacturer Interface

Scope of Work Breakdown

- Scope of Work of end user, designer, contractor, and manufacture varies project to project
- Fender manufacturer can assist through entire processes
- Basis of Design & Specification critical for defining the design inputs and required performance to ensure economical & durable fender system



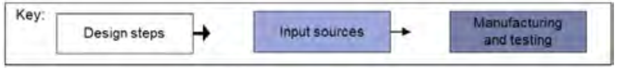


Figure 1.1: Flowchart WG 211 guideline

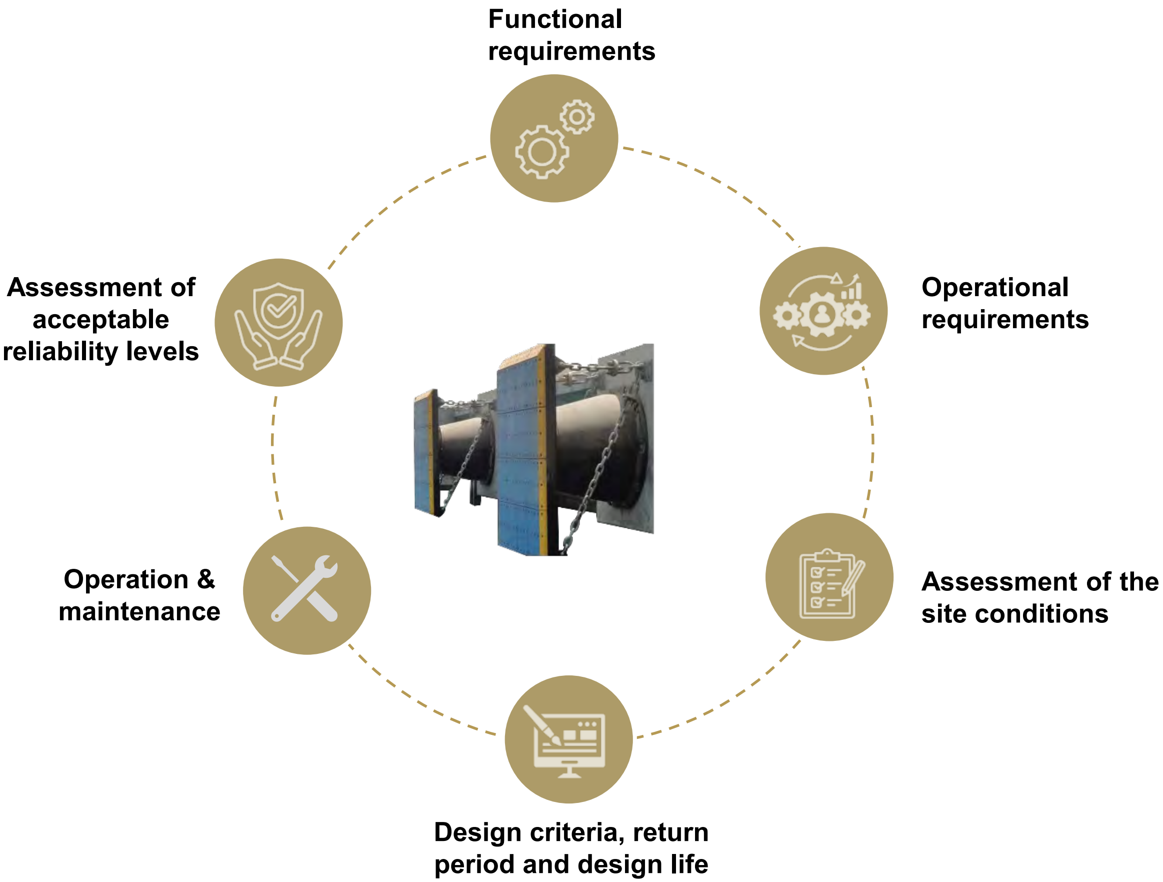
TRELLEBORG

Basis of Design

PIANC WG211 Chapter 4

- Chapter 4 - parameters that should be taken into consideration in the design of a fender system
- Roadmap for the design process OR template to develop BoD document
- Basis of design should consider all relevant factors that feed into the design

Fenders should be designed considering



"The design of a fender system deserves as much attention as the design of any other element of the structure of which it is a part."

PIANC WG211 Sec 4

Basis of Design

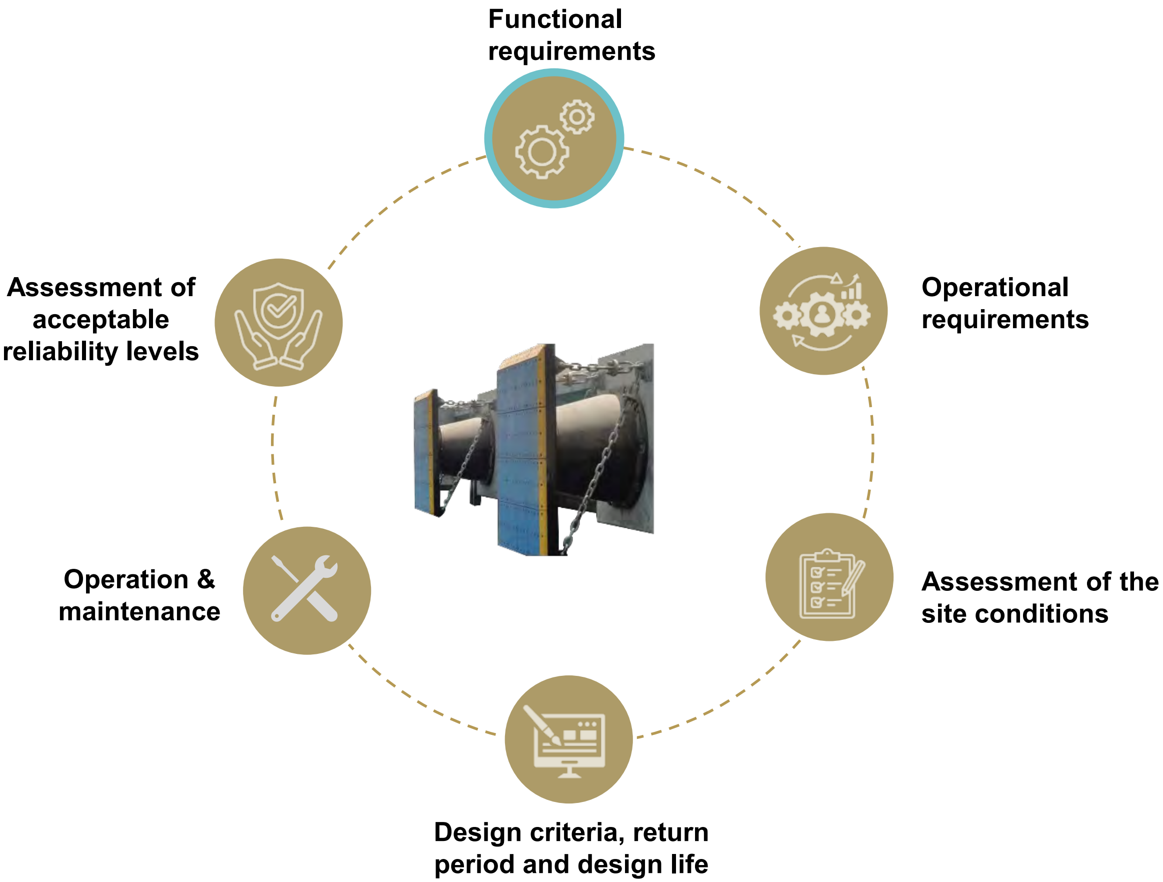
PIANC WG211 Chapter 4

Functional Requirements

Fender should be able to perform its functions within limitations in the BoD

Key considerations;

- Energy absorption or just protection?
- Non-marking requirements?
- Regular use or safeguard for accidents?
- Energy absorption in compression, shear or both?
- Is energy to be absorbed by the fender, structure, or both?



Basis of Design

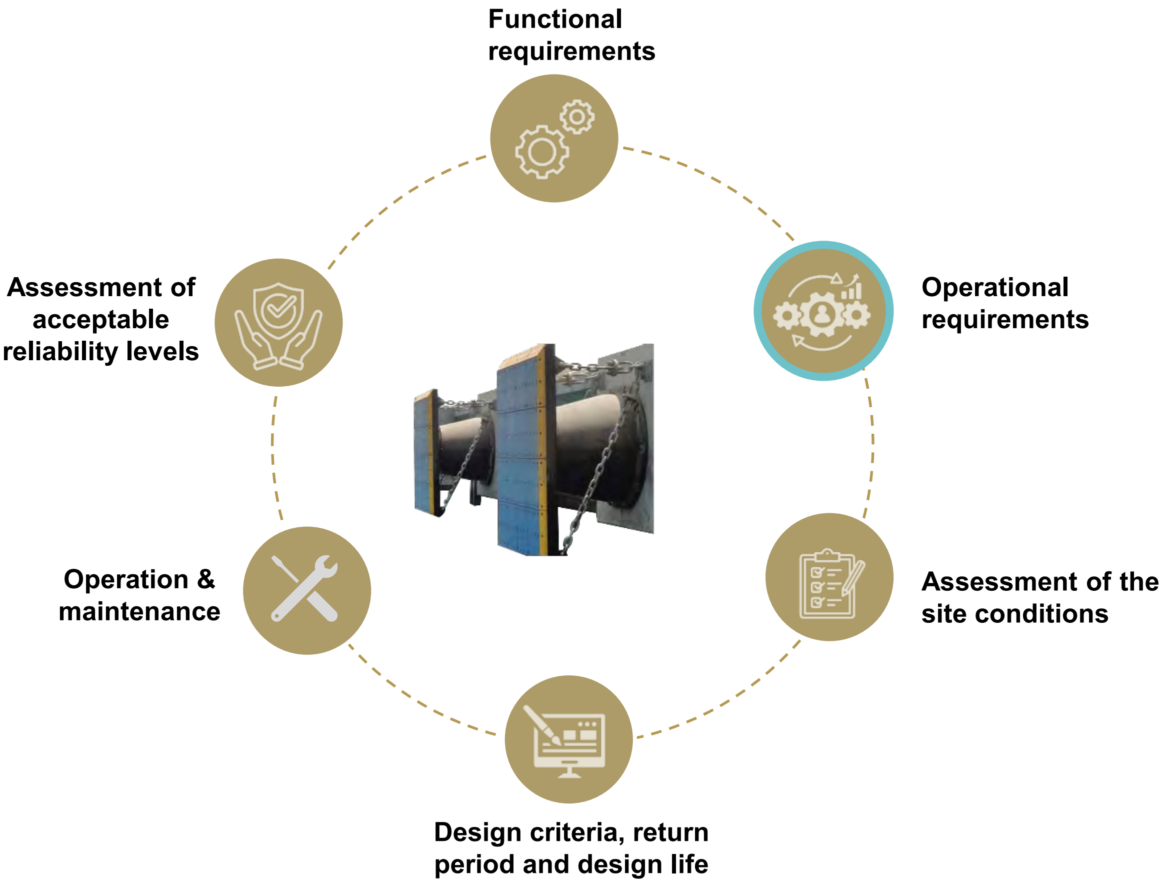
PIANC WG211 Chapter 4

Operational Requirements

Port to provide guidance on how the berth operates to inform the fender design

Key considerations;

- Vessel freeboard
- Berthing approach & fender contact
- Stand off restraints
- Survival and wave/wind design limits
- Operational limits imposed by adverse conditions
- Design life of fender system



Basis of Design

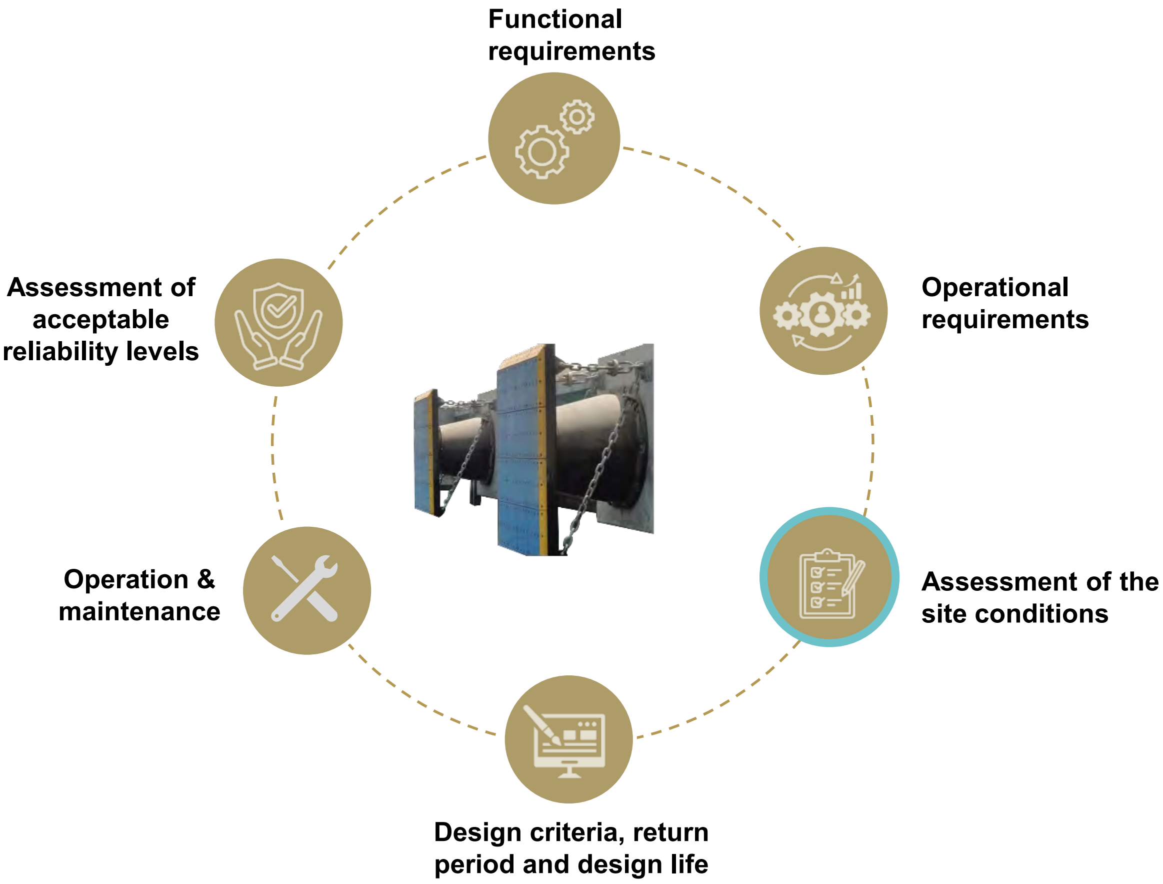
PIANC WG211 Chapter 4

Assessment of Site Conditions

Configuration & location of the berth to establish factors that impact fender design

Key considerations;

- Geographic location
- Wind/wave/current conditions/frequency
- Tidal range
- Water depth at berth & approach zone
- Wharf structure/load capacity/remaining service life



Basis of Design

PIANC WG211 Chapter 4

Design Criteria, return period and design life

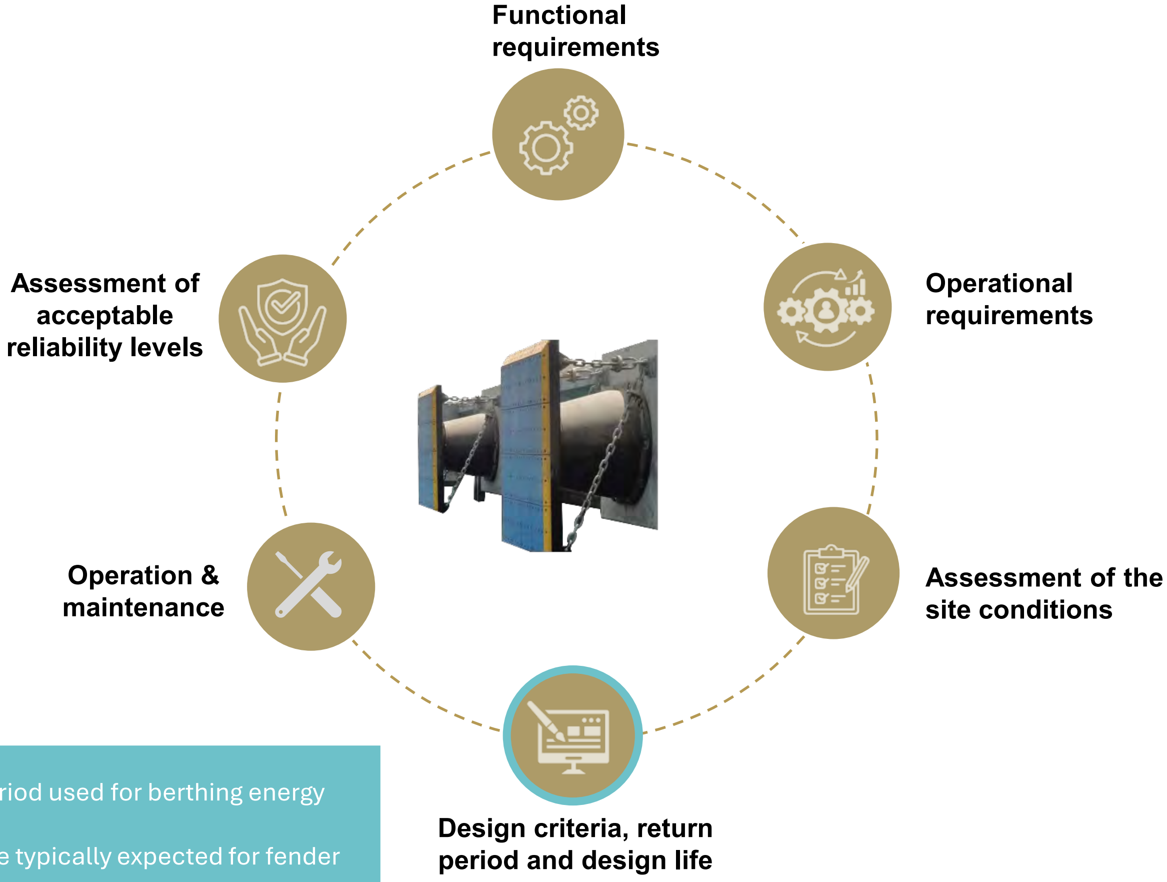
Design criteria used in calculating berthing energy & selecting fender system

Key considerations;

- Codes, standards and guidelines
- Design vessels & characteristics
- Maximum allowable reaction force
- Approach velocity/angle under normal/extreme conditions
- Berthing frequency
- Allowable hull pressure
- Design life
- Safety factors
- Whole life cycle considerations
- Maintenance periods

50-year return period used for berthing energy

20-year design life typically expected for fender systems



Basis of Design

PIANC WG211 Chapter 4

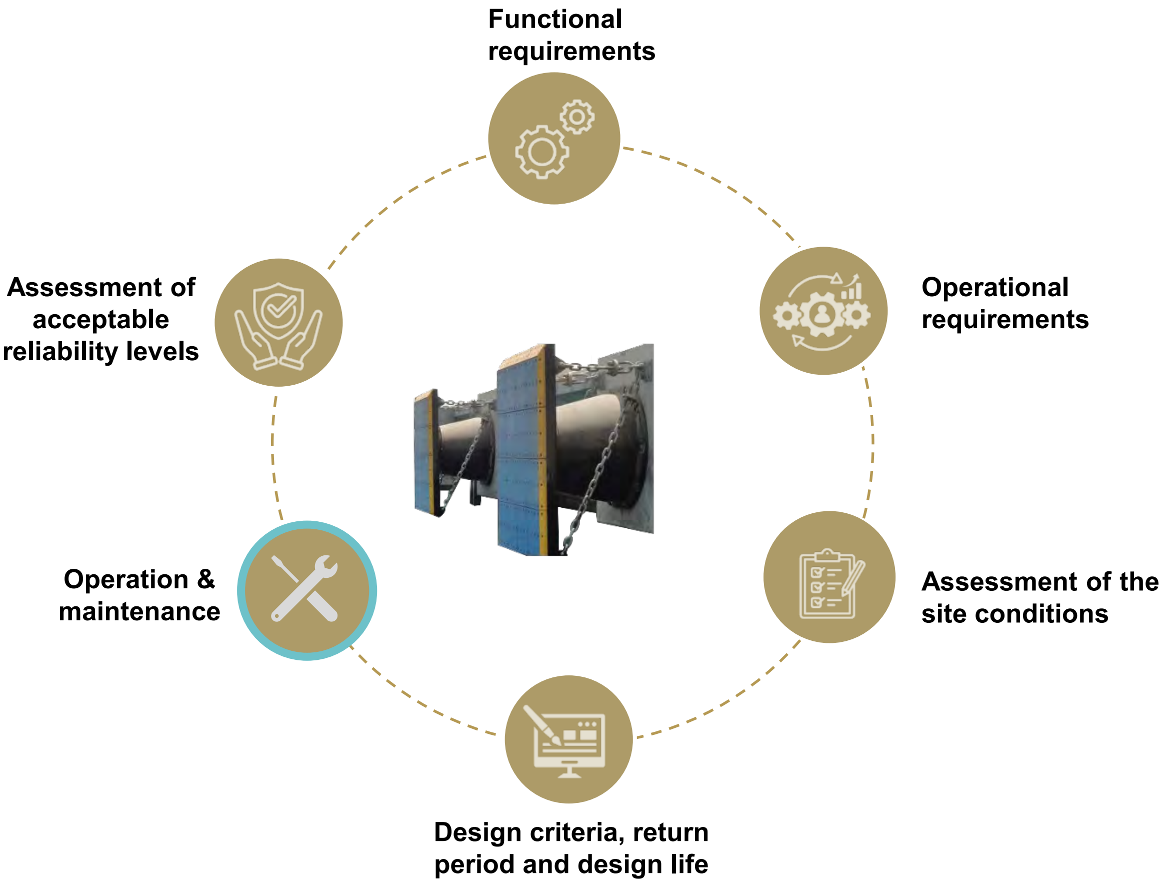
Operation & maintenance

To ensure fenders are functional across entire design life maintenance & inspection plans should be implemented.

Key considerations;

- WG103 (PIANC 2008) provides guidance
- Wharf Structures Condition Assessment Manual (WSCAM) provides framework
- CDIT; maintenance, 2019) “Japanese Guidelines for Management of Rubber Fenders
- Upcoming PIANC report 103 – “Life Cycle Management of Port Structures”

How a system is maintained needs to be considered during the design phase



TRELLEBORG

Basis of Design

PIANC WG211 Chapter 4

Assessment of acceptable reliability levels

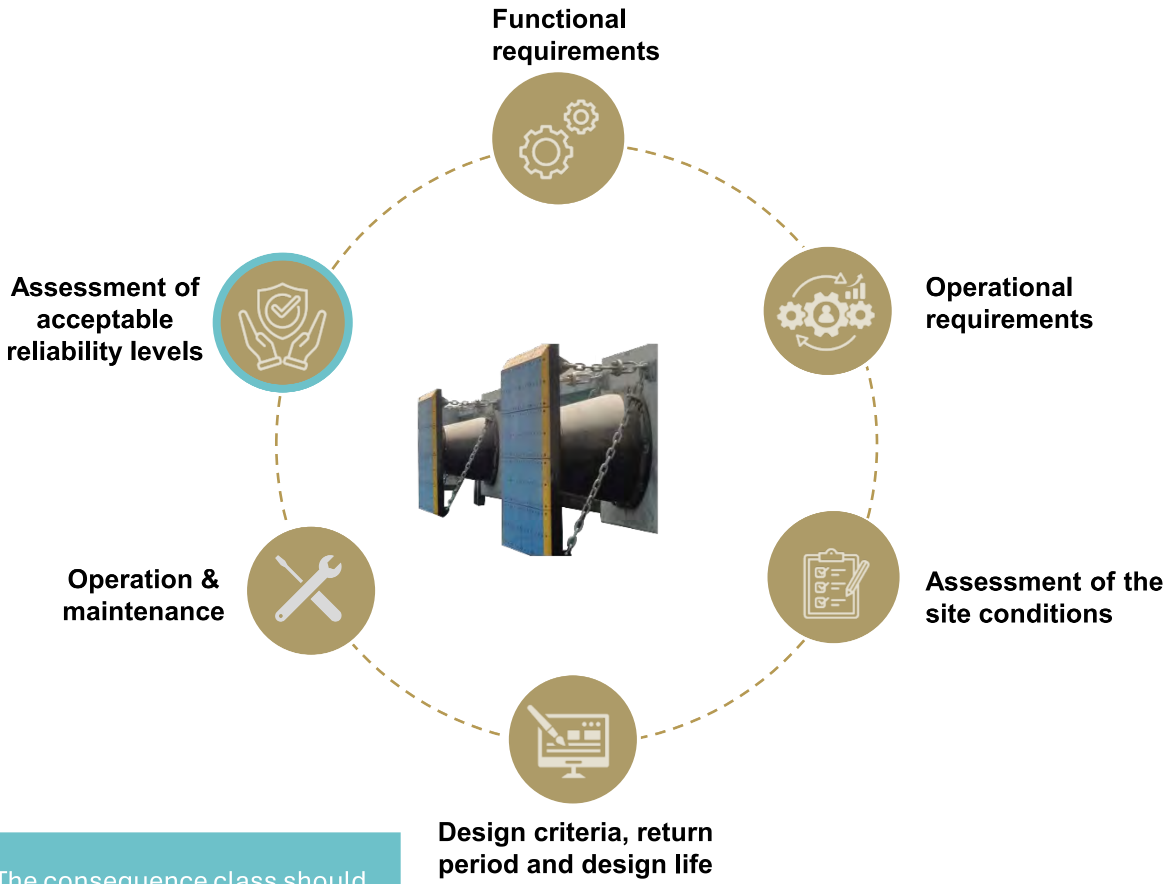
Determining & justifying of consequence class key during design phase

Key considerations;

- Increase consequence of failure = increased reliability requirement

Consequence class influences:

I. Partial energy factor (Chapter 5)
II. Partial safety factor for multiple fender contact (Chapter 6)
III. Partial load factor for fender system accessories design (Chapter 6)



"The consequence class should be selected by the asset owner"

Basis of Design

PIANC WG211 Chapter 4

Refer to PIANC WG211 table 4-1 for the entire table including description of failure consequence and explanations

Class	Description of failure consequences	Explanation	Example of fender systems
A	Negligible/ low consequences for risk of loss of human life AND environmental damage AND economic damage.	Failure of a single fender predominantly results in insignificant to no structural damage.	Fenders installed on a marine structure that is part of a terminal or port with functional redundancy [a] and limited number of people at risk. Failure of a single fender is not likely to result in the unavailability of the berth or widespread damage to the marine facility assuming there is sufficient redundancy with additional berths. An example can be a continuous earth retaining quay wall or a dolphin berth with more than two/ redundant berthing (breasting) dolphins or marine facilities with multiple berths having similar capabilities.
B	Some consequences for risk of loss of human life OR environmental damage OR economic damage.	Material damage **and** functionality losses of significance for owners and operators **and** low or no social impact.	Fenders installed on a marine structure without functional redundancy [a]. Failure[b] of the fender system is likely to result in the unavailability of the berth with no other alternatives. An example can be a single berth with two berthing (breasting) dolphins.
C	Considerable consequences for risk of loss of human life OR environmental damage OR economic damage.	Material losses **and** functionality losses of societal significance, causing regional disruptions **and** delays in important societal services over several weeks.	Fenders installed on marine structures, positioned at locations for which failure of the fender system is likely to put public lives at risk. Fenders installed on a marine structure for which failure[b] of the fender system is likely to close the berth and cause considerable consequential economic loss. Examples can be essential floating powerplants or floating storage regassification units that are prevented from operating after fender failure[b] and sufficient backup measures are available to resume operations.
D	High risk of loss of human life OR environmental damage OR economic damage.	Disastrous events causing severe losses of societal services **and** disruptions **and** delays at national scale over periods in the order of months.	Fenders installed on marine structures for which failure[b] of the fender system is likely to lead to significant socio-economic disruptions. Examples are progressive damage or cascading effects of other types of structures, e.g. critical installations such as essential powerplants or floating storage regassification units that are prevented from operating after fender damage with no backup measures available to resume operation.
E	Very high risk for loss of human life OR environmental damage OR economic damage.	Catastrophic events causing losses of societal services **and** disruptions **and** delays beyond national scale over periods in the order of years.	Beyond the scope of this guideline. In some cases, owners may choose, for practical reasons, to add an additional berthing criterion to cover 'Extreme Events' where additional energy is absorbed by partial collapse of secondary structural elements to protect critical wharf assets.

IMPACT ON THE INDUSTRY

- Functional, operational and site conditions are already common business practices but reenforces importance
- Design criteria (codes, design life, fatigue) considers various elements that was not well adopted in the past.
- Reliability requirement is a completely new element.

- Emphasizes the importance of providing the right level of information through the design process
- Underlines the importance of maintenance to achieve the design life
- Defines reliability requirements and the importance of end-user involvement

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Designer / Manufacturer Interface

Specification Writing (Chapter 13)

"Accurate & complete specifications are important to achieve an economical and durable fender system complying with the required performance"

- Basis of Design key document early in the project lifecycle
- Specification document should be issued during tender (contractor / manufacturer) to ensure economical & durable fender system

Basis of Design

Specification

Fender System Information	Purchaser (designer, contractor, end user, port authority)	Supplier (contractor, manufacturer)	Chapter
General port and quay information	X		-
Water levels, depth and met-ocean conditions	X		-
Fender system selection	X	X	2 & 6
Design vessel information such as displacement, draught, length, beam, hull characteristics, etc.	X		3
Consequence class and design life	X		4
Vessel berthing and navigation consideration, **berthing velocity** and angle, tug assisted or not, etc.	X		5
Manufacturing, durability and quality requirements	X		9
Testing requirements	X		10
Additional design specification notes (optional)	X		-
Preliminary design (optional)	X		-
Final design including rubber fender properties		X	-
Installation, maintenance and storage manuals		X	11
Recycling, rubber sourcing, carbon footprint, etc. note	X	X	12
Approval of final design criteria	X		-

Table 13-1: Required fender system design information

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Specification Writing

PIANG WG211 Chapter 13

13.1 General Information

13.2 Basis of Design

13.3 Manufacturing, Testing and Quality Requirements

13.4 Delivery Installation and Storage

13.5 Sustainability

Verification

Essential step: Ensure that what is designed for & specified is manufactured and supplied

A strong specification means:

- Reduced **cost over life** of fender asset
- Lower OPEX (increased service life / lower maintenance costs)
- Increase port efficiency and safety
- Reduce liability for all stake holders

WG211 & Emerging Technology

Emerging Technology

WG211 Site Specific Data

Chapter 1 “Introduction”

- WG 211 strongly recommends the use of site-specific information.
- When site-specific information is used, fenders will be slightly smaller than those determined using WG 33
- If local knowledge is ignored, fenders might be over designed.

Chapter 5 “Berthing Energy”

- 5.4.1. recommends that site-specific information and experience are used where available when defining the characteristic berthing velocity, e.g. berthing records, etc.
- Same principle applies to berthing angles
- Section 5.8 allows for a lower “Partial Energy Factor” when the berth is monitored resulting in a lower berthing energy and thus smaller fenders

Chapter 11 “Installation, Inspection and Maintenance”

- Section 11.3.3 “Emerging Technology”

Emerging Technology

WG211: Site Data & Berthing Velocity

Characteristic Berthing Energy

$$E_{k,c} = \left(\frac{1}{2} M_c V_c^2\right) C_{e,c} C_{m,c}$$

Design Variable	Characteristic Value
Berthing velocity (V_c)	0.02 % of probability being exceeded per berthing manoeuvre
Displacement (M_c)	Largest operational displacement of the design vessel resulting in the highest characteristic berthing energy
Berthing angle (α_c)	5 % probability of exceedance per berthing manoeuvre

Table 5-2: Recommended characteristic values of design variables

Navigation Condition:	Favourable	Moderate	Unfavourable
Type of Vessel[a]	$V_{B,c}$ (m/s)		
Coaster	0.180[f]	0.300[e]	0.400[e]
Feeder, Handysize	0.150[b]	0.225[c]	0.300[d]
Handymax, Panamax	0.120[b]	0.200[e,g]	0.275[d]
Vehicle Carriers	0.120[e]	0.200[e]	0.275[e]
Post Panamax, Capesize (small), Aframax	0.100[b,e]	0.175[c]	0.275[d]
New Panamax, Capesize (large), Suezmax, ULCV, VLBC, VLCC, ULCC	0.100[b,e]	0.150[c,f]	0.250[d]
Cruise & Passenger Vessels	0.100[e]	0.150[e,f]	0.250[e]

Table 5-3: Characteristic berthing velocity in the absence of site-specific information

Using local knowledge is the essence of this guideline. The velocities presented in Section 5.4.3 and 5.4.3 should only be used if local data, information, and experience is lacking. These velocities are considered to be safe and based on a global dataset therefore have a tendency to be conservative.

Emerging Technology

WG211: Site Data & Partial Energy Factor

Design Berthing Energy

$$E_{k,d} = \gamma_E E_{k,c}$$

Partial Energy Factor

$$\gamma_E = \gamma_{E,ref}\, \gamma_n\, \gamma_p\, \gamma_c$$

Where:

$\gamma_{E,ref}$ Reference partial energy factor for 100 berthings per year

γ_n Correction factor for alternative annual berthing frequencies; see Step 6

γ_p Correction factor for berthings without pilot assistance; see Step 7

γ_c Correction factor for correlations between design variables; see Step 8

Monitored berthing

Potential $\gamma_{E,d}$ reduction: -3.8% to -31%

Navigation Condition	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Favourable	High	1.30	1.50	1.60	1.70
	Moderate	1.35	1.55	1.65	1.80
	Low	1.50	1.70	1.80	1.95
Moderate	High	1.35	1.60	1.70	1.85
	Moderate	1.45	1.65	1.75	1.90
	Low	1.60	1.80	1.90	2.10
Unfavourable	High	1.50	1.85	2.00	2.20
	Moderate	1.60	1.95	2.05	2.30
	Low	1.80	2.15	2.30	2.55

Table 5-8: Reference partial energy factor [$\gamma_{E_{ref}}$] for 100 berthings per year – single fender contact

-0.05

Navigation Condition	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Favourable	High	1.15	1.35	1.40	1.50
	Moderate	1.20	1.40	1.55	1.55
	Low	1.35	1.50	1.60	1.70
Moderate	High	1.20	1.40	1.45	1.60
	Moderate	1.25	1.45	1.55	1.65
	Low	1.40	1.60	1.70	1.80
Unfavourable	High	1.25	1.55	1.65	1.85
	Moderate	1.35	1.60	1.75	1.95
	Low	1.50	1.80	1.95	2.15

Table 5-9: Reference partial energy factor [$\gamma_{E_{ref}}$] for 100 berthings per year – multiple fender contact

-0.8

Monitored berthing	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Single fender contact	High	1.25	1.40	1.45	1.55
	Moderate	1.30	1.45	1.50	1.60
	Low	1.40	1.55	1.65	1.75
Multiple fender contact	High	1.10	1.25	1.30	1.40
	Moderate	1.15	1.30	1.35	1.45
	Low	1.30	1.45	1.50	1.60

Table 5-10: Reference partial energy factor [$\gamma_{E_{ref}}$] for 100 berthings per year – for Monitored Berthings

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WG211: Site Data & Partial Energy Factor

Design Berthing Energy

$$E_{k,d} = \gamma_E E_{k,c}$$

Partial Energy Factor

$$\gamma_E = \gamma_{E,ref}\, \gamma_n\, \gamma_p\, \gamma_c$$

Where:

$\gamma_{E,ref}$	Reference partial energy factor for 100 berthings per year
γ_n	Correction factor for alternative annual berthing frequencies; see Step 6
γ_p	Correction factor for berthings without pilot assistance; see Step 7
γ_c	Correction factor for correlations between design variables; see Step 8

Monitored berthing	CoV_M	Reference partial energy factor for consequence classes [$\gamma_{E_{ref}}$]			
		A	B	C	D
Single fender contact	High	1.25	1.40	1.45	1.55
	Moderate	1.30	1.45	1.50	1.60
	Low	1.40	1.55	1.65	1.75
Multiple fender contact	High	1.10	1.25	1.30	1.40
	Moderate	1.15	1.30	1.35	1.45
	Low	1.30	1.45	1.50	1.60

Table 5-10: Reference partial energy factor [$\gamma_{E_{ref}}$] for 100 berthings per year – for Monitored Berthings

Typical reductions:

- Jetties: -13.8% (Consequence class B, Moderate, Low)
- Container: -4.3% (Consequence class A, Favorable, High)

“Another method to control uncertainty in berthing energy is to monitor the berthing velocity. When masters and pilots are aware of realistic berthing speed limits AND when berthing aid systems are used, such as portable pilot units or fixed shore-based docking systems, this is defined as monitored berthing and lower partial energy factors can be taken into account.”

Emerging Technology

WG211: Positive effects of vessel size & velocity correlations

$$\gamma_E = \gamma_{E,ref}\,\gamma_n\,\gamma_p\,\gamma_c$$

Partial Energy Factor Step 8:

PIANC WG 145 [vessel berthing records] do not show a strong relation between vessel size and berthing velocity

no correlation between vessel size & berthing velocity: $\gamma_c = 1.0$

correlation between vessel size & berthing velocity: $\gamma_c < 1.0$*

Where site-specific information is available…it is recommended to quantify the effect of correlations between design variables.

Roubos, Iversen, & Oskamp, 2024 found that γ_c is close to 0.6 for a container terminal with favourable navigation conditions in Rotterdam

Trelleborg Smart Products

SmartDAS Product Overview

Features

- Compact, easy to install docking aid for non-Haz areas
- Accommodates varied mooring configurations or continuous berths
- Infrared, Eye-safe to Class 1 – Industry standard & zero OH&S issues
- Captures vessel distance, velocity & longitudinal angle
- Web application for real time & historic data
- Event based – match vessel AIS information to berthing data
- Vessel detection at 200m range / Accurate to +/- 2cm

Benefits:

- Safe, efficient, and reliable berthing operations
- Configurable alarm functionality
- Asset Protection
- Data logging & historical records
- Data insights for improved operations and investment decisions

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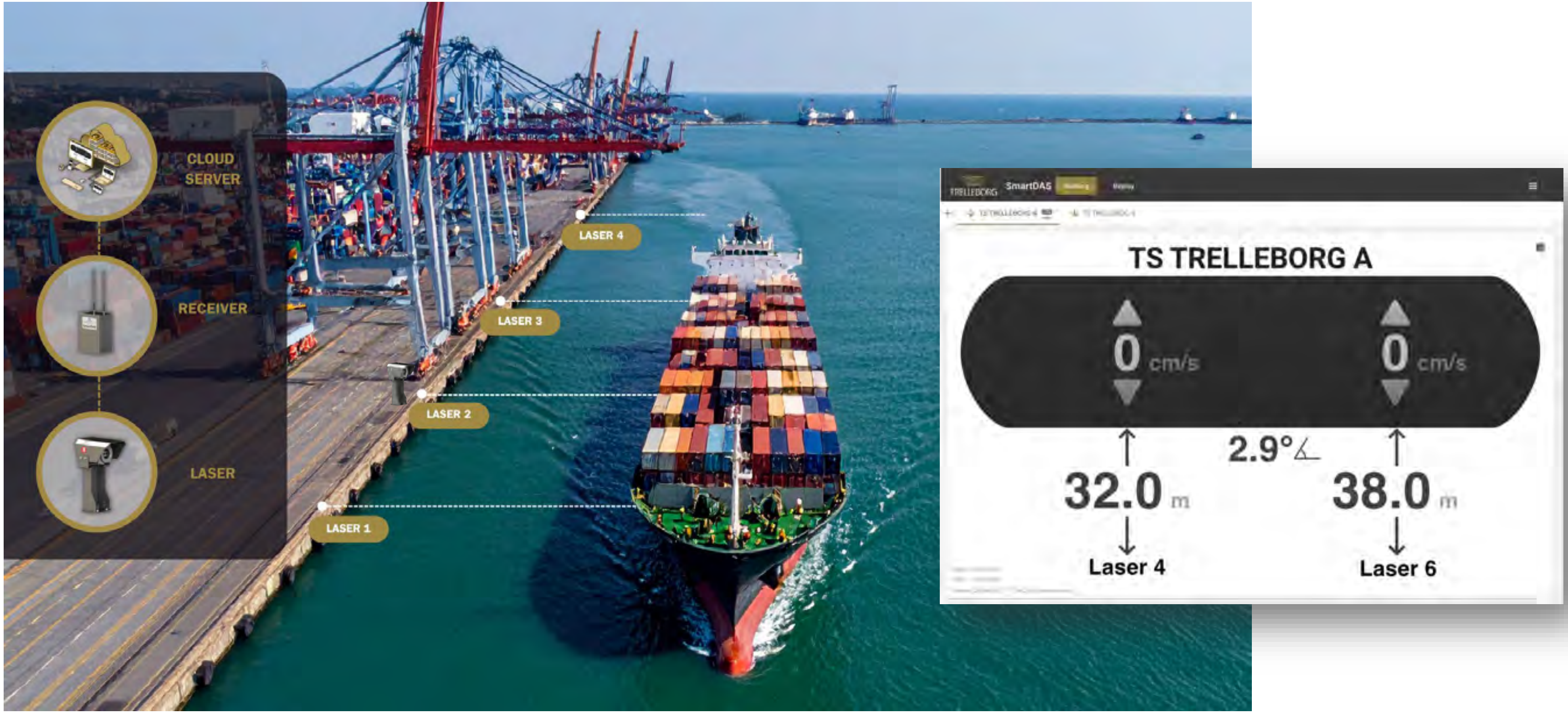
How does a SmartDAS work



WG211 Monitored Berthing

WG211 DAS Example - Container

			Not monitored SCN1600 F3.0	Monitored SCN1600 F2.6
Displacement	M_D	t	307,000	
Berthing Velocity	VB,c	m/s	0.150	
Added Mass Coefficient	C_M		1.743	
Eccentricity Coefficient	C_E		0.712	
Characteristic Berthing energy	$E_{K,c}$	**kNm**	**4286**	
Reference Partial Energy Factor	$\gamma_{E,ref}$		1.25	1.15
Alt. annual berthing frequencies	γ_n		1.00	1.00
Berthing's without pilot assistance	γ_p		1.00	1.00
Corr. between design variables	γ_c		1.00	1.00
Design Berthing Energy	$E_{K,d}$	**kNm**	**5354**	**4926**
Base performance	E_{base}	**kNm**	**2480**	**2268**
Characteristic performance	$E_{f,c}$	kNm	5956	5447
Design performance	$E_{f,d}$	**kNm**	**5415**	**4952**
	$R_{f,d}$	**kN**	**4772**	**4206**

Key Assumption:

- **Consequence Class A**
- **Moderate conditions**
- **Fender spacing 15 m**
- **Multiple fender contact**
- **1000m berth – 67 fenders**

11.9% reduction

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WG211 Monitored Berthing

WG211 DAS Example - Jetty

			Not monitored SCN2500 F2.4	Monitored SCN2500 F1.9
Displacement	M_D	t	320,000	
Berthing Velocity	VB,c	m/s	0.150	
Added Mass Coefficient	C_M		1.80	
Eccentricity Coefficient	C_E		0.747	
Characteristic Berthing energy	$\mathbf{E_{K,c}}$	**kNm**	**4844**	
Reference Partial Energy Factor	$\gamma_{E,ref}$		1.65	1.45
Alt. annual berthing frequencies	γ_n		0.96	1.00
Berthing's without pilot assistance	γ_p		1.00	1.00
Corr. between design variables	γ_c		1.00	1.00
Design Berthing Energy	$\mathbf{E_{K,d}}$	**kNm**	**7670**	**6741**
Base performance	$\mathbf{E_{base}}$	**kNm**	**8234**	**7266**
Characteristic performance	$E_{f,c}$	kNm	8520	7518
Design performance	$\mathbf{E_{f,d}}$	**kNm**	**7745**	**6834**
	$\mathbf{R_{f,d}}$	**kN**	**10151**	**8753**

Key Assumption:

- **Consequence Class B**
- **Moderate conditions**
- **No multiple fender contact**
- **4 Fender systems**

13.8% reduction

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Fabrication & Quality Control

Fender Fabrication & Testing

PIANC WG211

- Chapter 9 - Manufacturing of Fender Systems
- Chapter 10 - Test Procedure of Marine Fenders

Manufacturing of Fender Systems

PIANC WG211 - Chapter 9

- Manufacturer Qualifications
- Rubber Fender Compound
- Manufacturing Process of Rubber
- Fabrication Of Steel panels
- Fabrication of UHMW-PE Low Friction Facing
- Fabrication of Accessories
- Pneumatic Fenders
- Foam Fenders

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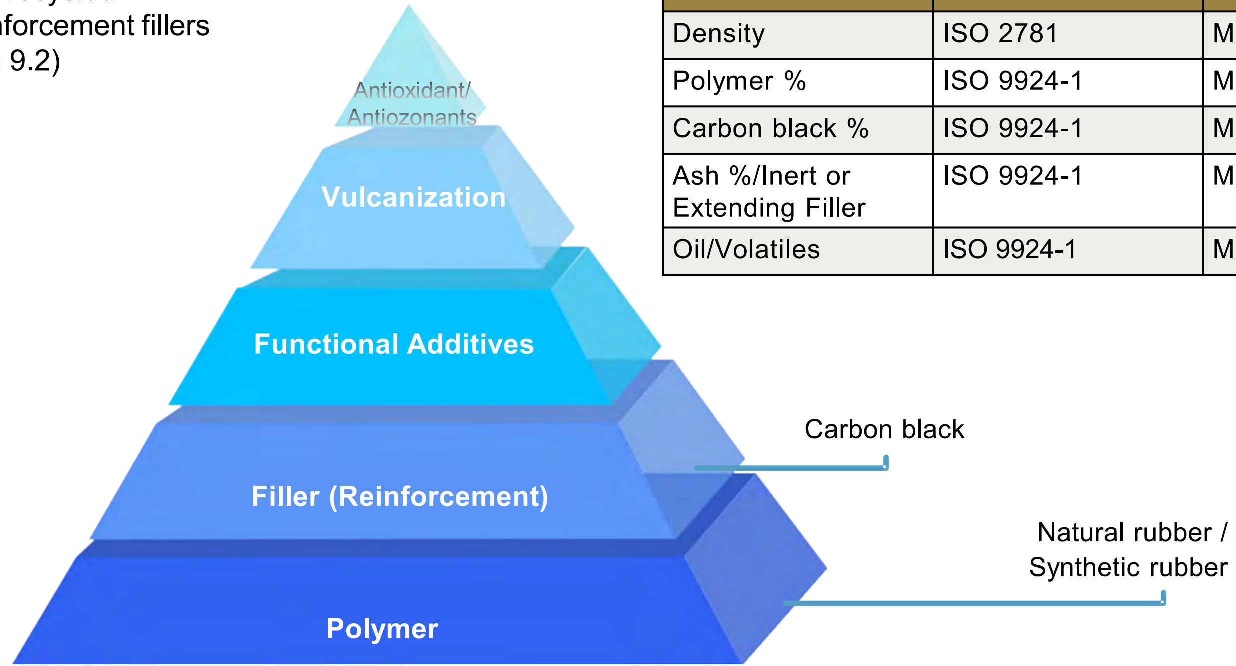
Manufacturing of Fender Systems

Rubber Compound

To eliminate the risk for recycled compound and non-reinforcement fillers (PIANC WG211 section 9.2)



Compounding Structure

Test	Standard	Specification
Density	ISO 2781	Max 1.20 g/cc
Polymer %	ISO 9924-1	Min 45%
Carbon black %	ISO 9924-1	Min 20%
Ash %/Inert or Extending Filler	ISO 9924-1	Max 6%
Oil/Volatiles	ISO 9924-1	Max 29%

Rubber Fender Manufacturing Process

Compounding and Mixing

Moulding/ Building

Curing

For more detailed information on the manufacturing process, see our Manufacturing Methods Matter whitepaper

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Fender Panel Manufacturing

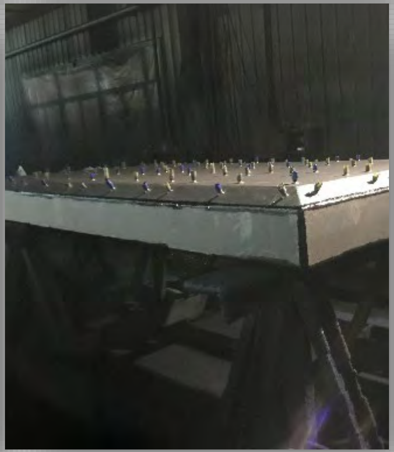
Qualifications and standards

Qualifications of steel workshop

- ISO9001 certified
- All WPQR, WPS, PQR updated & certified
- Clean professional workshop
- Incoming material control
- Quality department separate from manufacturing department
- Documentation
- Dedication paint shop with qualified people and separate indoor blasting area
- Detailed ITP in place

Fabrication Standards

- Welding Standards (i.e. AWS D1.1, AS 1554)
- Material Standards (i.e. ASTM A572, Q355b, or Eq.)



Fender Panel Manufacturing

Internal and External Construction

Typical Internal Cross Sections

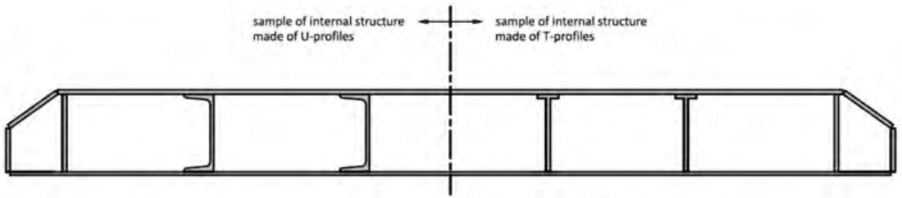


Figure 9.2: Typical fender panel cross section samples (U profile on left, T-profiles on right side

Typical Structure

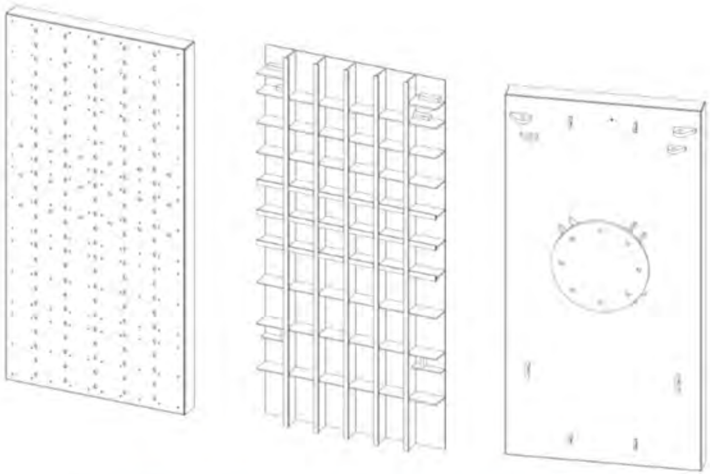


Figure 9.3: Typical fender frontal, back and internal panel structure views

Fender Panel Manufacturing - Painting

Critical steps in paint application:

Surface Preparation

- Degreasing
- Blasting
- Surface cleanliness
- Dedusting
- Surface Profile
- Soluble salts

Paint Application

- Environmental conditions
- Dry film thickness
- Holiday detection
- Adhesion testing
- Visual test

Critical element in the fabrication process than impacts durability and maintenance of the fender panel significantly.

A paint system might be selected correctly (i.e. ISO 12944:2019 IM2) but when not applied correctly the longevity of the paint system will be significantly less than designed for

Manufacturing of Fender systems: UHMW-PE

Functional aspects:

- **Wear resistance** — Impacts durability & differentiator to low- cost material
- **Coefficient of friction** — Impacts design parameters
- **Charpy impact strength** — Impacts durability & differentiator to low- cost material

Testing aspects:

- **MFI** — Differentiator to low-cost material
- **Density** — Differentiator to low-cost material

UHMW-PE Resin and Pads

No.	Property	Test method	Unit	Requirement (virgin)	Requirement (regenerated)	Comments
1	Density	ISO 1183-1	g/cm^3	0.920-0.945	0.930-0.955	
2	Tensile strength at yield	ISO 527-2	MPa	17 - 21	Min. 17	
3	Elongation at break	ISO 527-2	%	Min. 150	Min. 150	
4	Hardness	ISO 868	HDD	60-65	60-70	Shore D
5	Double notch Charpy Impact Strength	ISO 21304-2	KJ/m^2	Min. 120	Min. 70	Average of four samples
6	Abrasion resistance (sand slurry test)	ISO 15527	ml/g	Max. 110	Max. 150	Average of min. two samples. Sample preparation: ISO 11542
7	Mass Melt-flow rate (MFI)	ISO 1133 (@190° C, 21.6 Kg	g/10 min	0 to 0.1	0 to 0.3	Samples from the pads can be used for testing.
8	Friction coefficient (Static, Dry)	ISO 8295 (with Steel)	—	Min. 0.2	Min. 0.2	
9	Molecular weight	ISO1628-3	g/mol	~ 5.0×10^6	~ 2.0×10^6	For selection of material, testing is not needed.

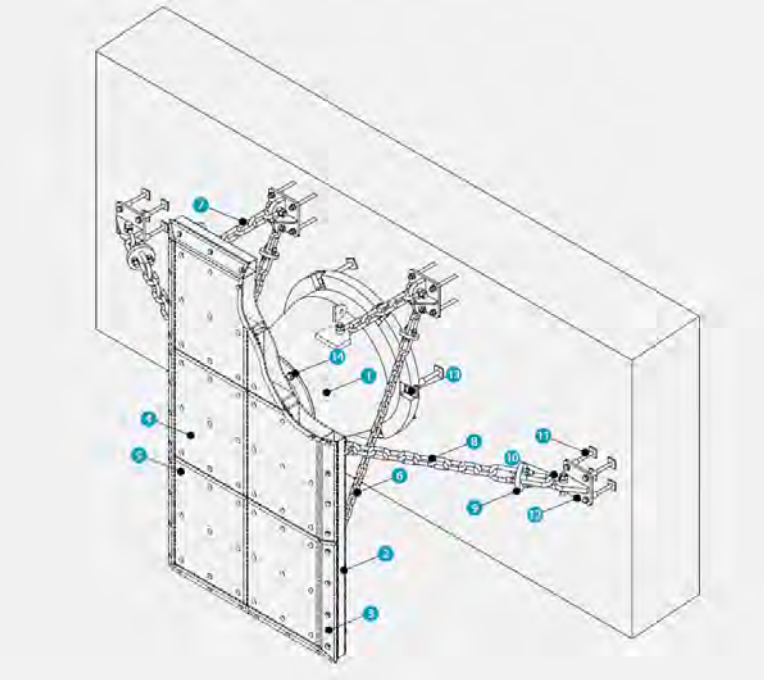
Notes:

1. Pads are produced through the compression moulding process, using high temperature and pressure, with granular UHMW-PE resins.
2. The supplier is required to furnish a material testing certificate, encompassing properties such as density, tensile strength, elongation, abrasion resistance, hardness, and Charpy impact strength. The material certificate should comply with the specifications of a 3.1 certificate as per EN 10204 or an equivalent standard.
3. To ensure quality assurance, the end user has the option to validate the quality by obtaining samples from randomly selected pads and conducting tests for density, impact strength, abrasion resistance, and MFI (melt flow index) at an independent third-party laboratory.
4. The UHMW-PE moulder should provide the specifications and quantities for the moulded products. The frequency of testing should involve conducting one test per production lot or adhering to an agreed sampling scheme established between the customer and the manufacturer.
5. Regenerated UHMW-PE presents a potential sustainable alternative to virgin material. However, for heavy-duty applications such as belted vessels, the use of virgin material is recommended to ensure optimal performance and durability.

Table 10-12: Physical Properties of UHMW-PE resin and pads

See PIANC WG211 table 10-12 for detailed properties

Fender Panel Manufacturing - Accessories



Fender Panel Accessories:

- Chain Assemblies
- Anchors and fixing hardware

Manufacturing processes for these items are largely standardised to international standards, but QA/QC still should be tightly controlled and thoroughly checked to ensure proper material quality for a fender system.

Pneumatic Fender Manufacturing Process

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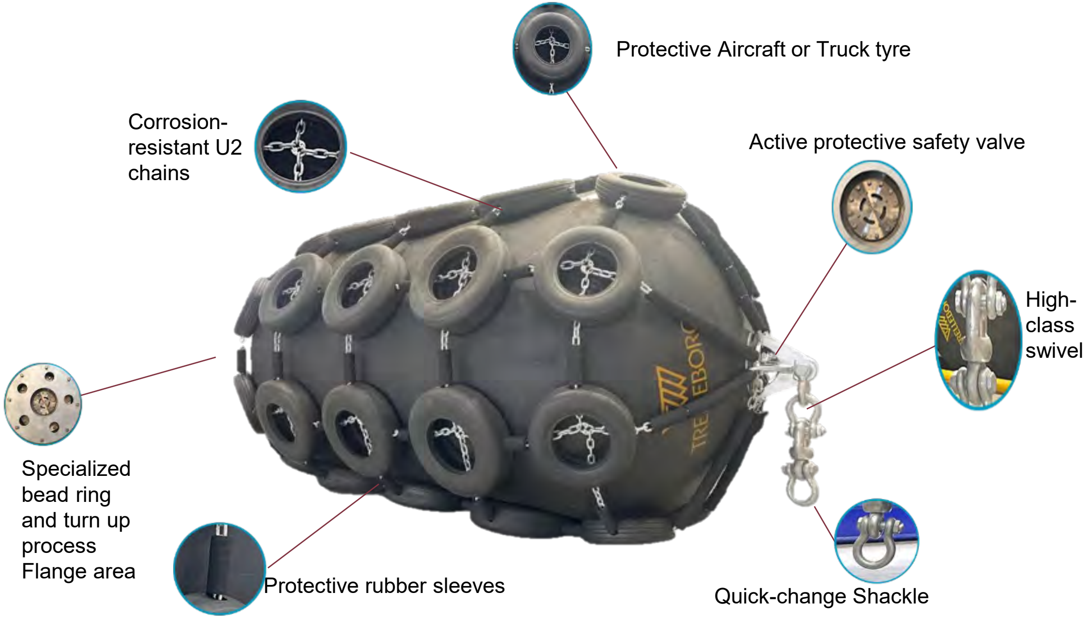
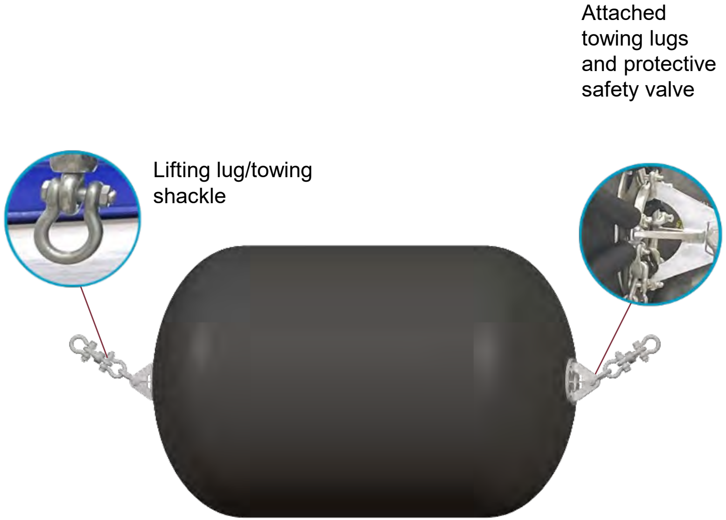
Manufacturing of Fender Systems – Pneumatic Fenders

Pneumatic Fender Types

CTN FENDERS (TYPE I)



SLING FENDERS (TYPE II)



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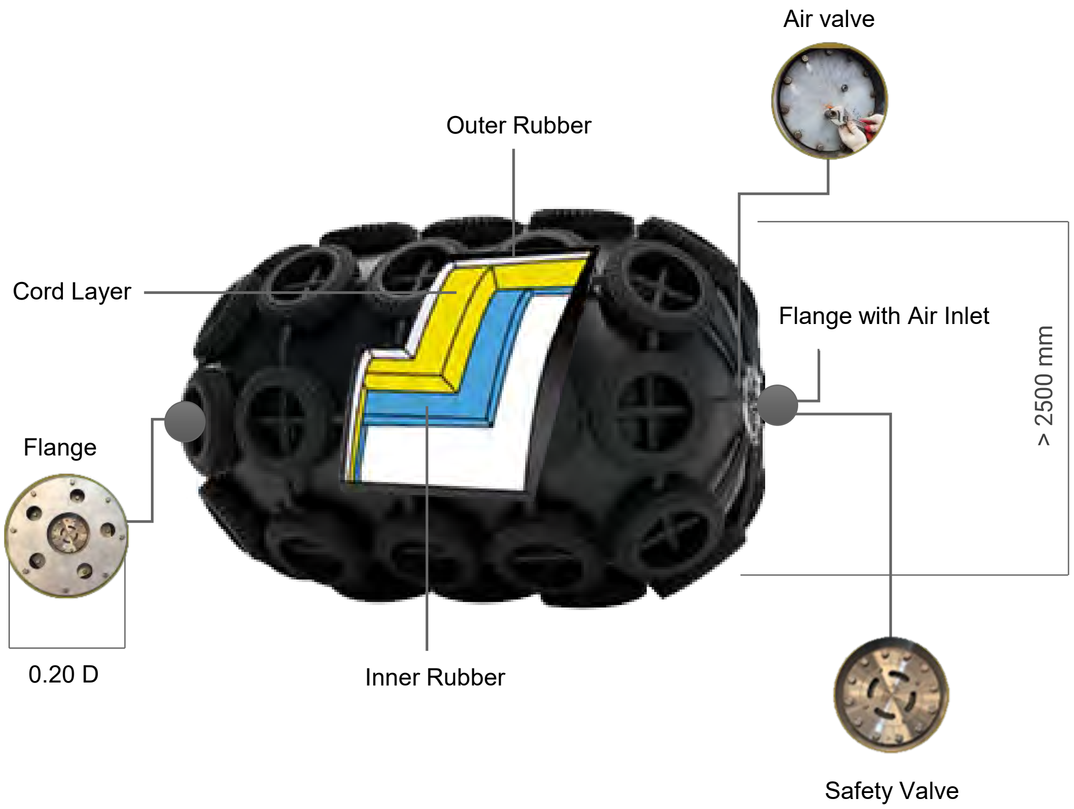
Manufacturing of Fender Systems – Pneumatic Fenders
ISO17357-1: 2014



Manufacturing

Pneumatic fenders are produced inside a mold. The mold sits on two rollers to easily rotate the molds during the building process.

The cylindrical mold has multiple detachable parts: two hemispheric end parts and two straight body parts.

Side view of a mold showing the flange opening

Testing & Qualification – ISO 17357-1:2014

Prototype – Qualification

Angular, compressions, durability, compression recovery, puncture resistance, fatigue, and heat radiation testing to verify design

Commercial Fenders

TGA, dimensional, hydrostatic, and air leakage tests to verify commercial product

- Markings
- Inspection and evaluation by a qualified independent inspection service

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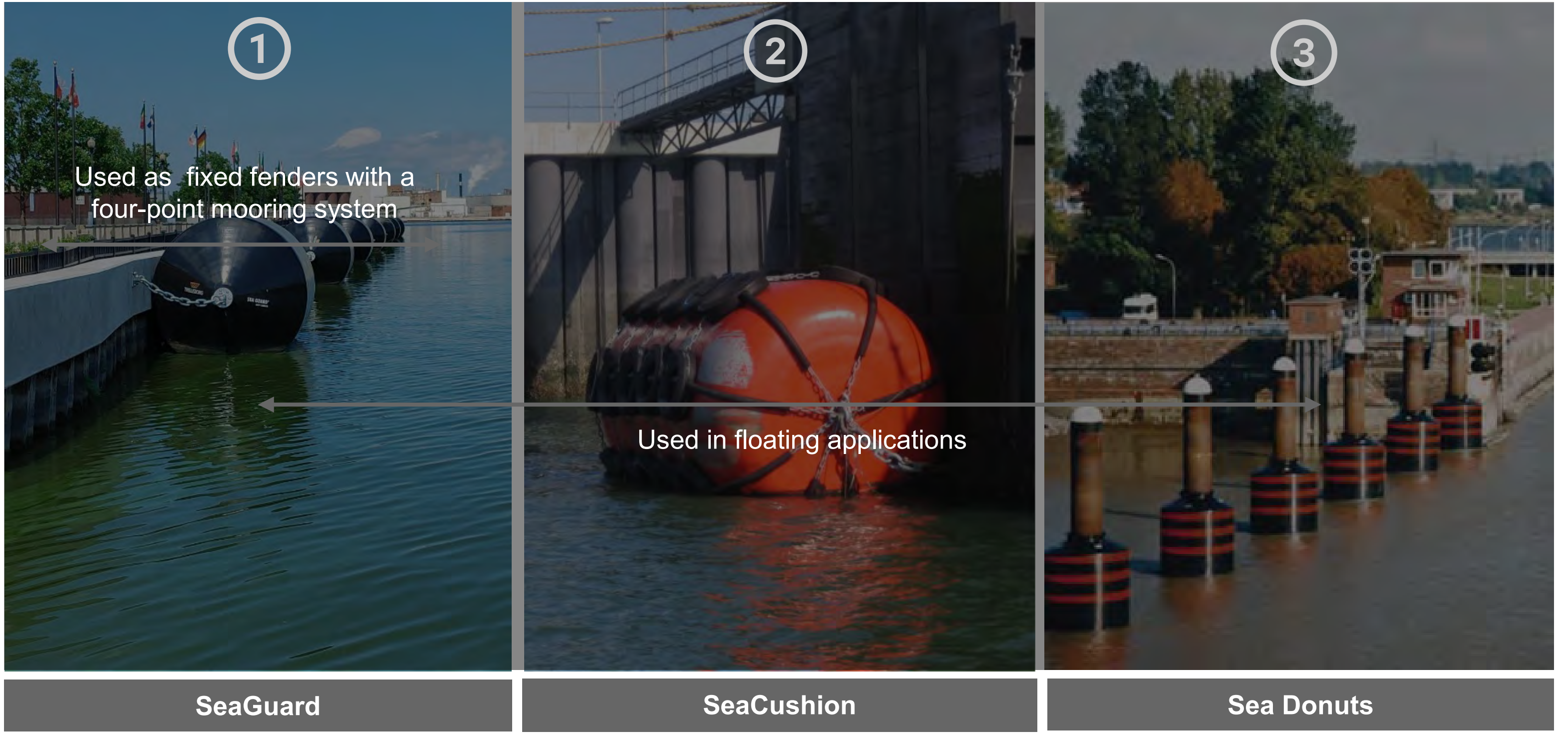
Foam Products: Manufacturing Process

Types of Foam Fenders



Energy absorption is achieved by compressing closed cell foams. Performance variation is achieved via a combination of foam density selection and physical shape and size to achieve the desired performance.

Mandrel Readied for Foam

Sea Guard Mandrel

End fittings Sized based on fender size and performance.

Donut Mandrel

Secured to ID of Donut core.

Foam Staged for Winding / Lamination

Foam Wound to Mandrel

Foam thermo-laminated during winding

Winding complete

Fender Trimmed to Size and End Angle

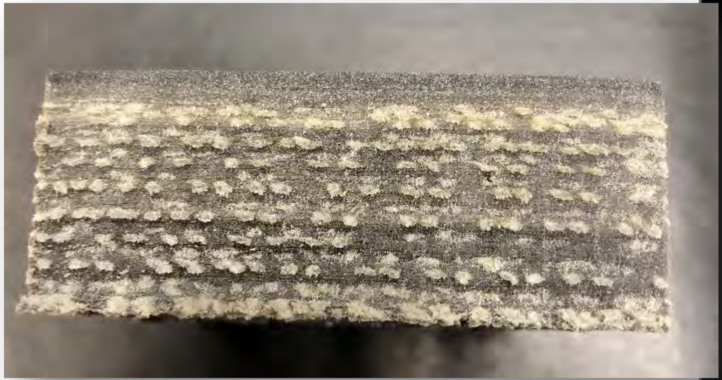
Wound Foam – Temperature Normalization

Composite Urethane / Nylon Skin Applied

Skin thickness is determined by reaction force.
So as such defined by foam density and fender size.

Thickness measurements are taken during this process to ensure it confirms to requirements

The PU / Nylon Composite Skin



Property (Elastomer only)	Unit	Typical Result
Hardness	Shore A	75-95
Tensile Strength (PU only)	Map	>13.8
Elongation at Break (PU only)	%	>300
Tear Strength	kN/m	>32
Flexural Life (ross)	Cycles	>10000
Abrasion Resistance	NBS	>100

Property (Elastomer/Nylon)	Unit	Typical Result
Tensile Strength (single Filament)	MPa	31
Elongation at Break	%	16
Helix Angle	degrees	45 - 60
Filament Spacing	mm	<4
Tear Strength	kN/m	78.8

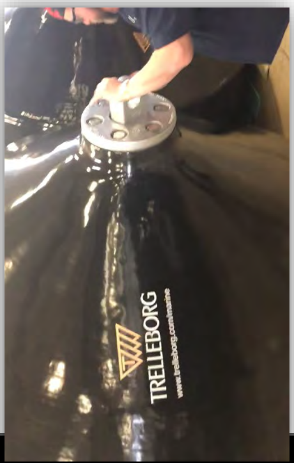
Skin Curing

Fender removed from spray booth and allowed to cure per material specifications

Additional thickness measurements are taken during this process to ensure it confirms to requirements

Finishing

Fenders are finished with Logos and Serial numbers



Internal chains are pulled through the fender core and secured.
Swivel and capture plates secured

Test Procedures of Marine Fenders

Test procedure of marine fenders

WG211 Chapter 10

- Much better-defined processes – clear and with less room for ambiguity
- Clearer for 3rd parties and requirements for 3rd parties
- Significant amount of testing required
- Traceability requirements (TGA)
- Covering solid fenders & foam fenders and accessories
- Special testing

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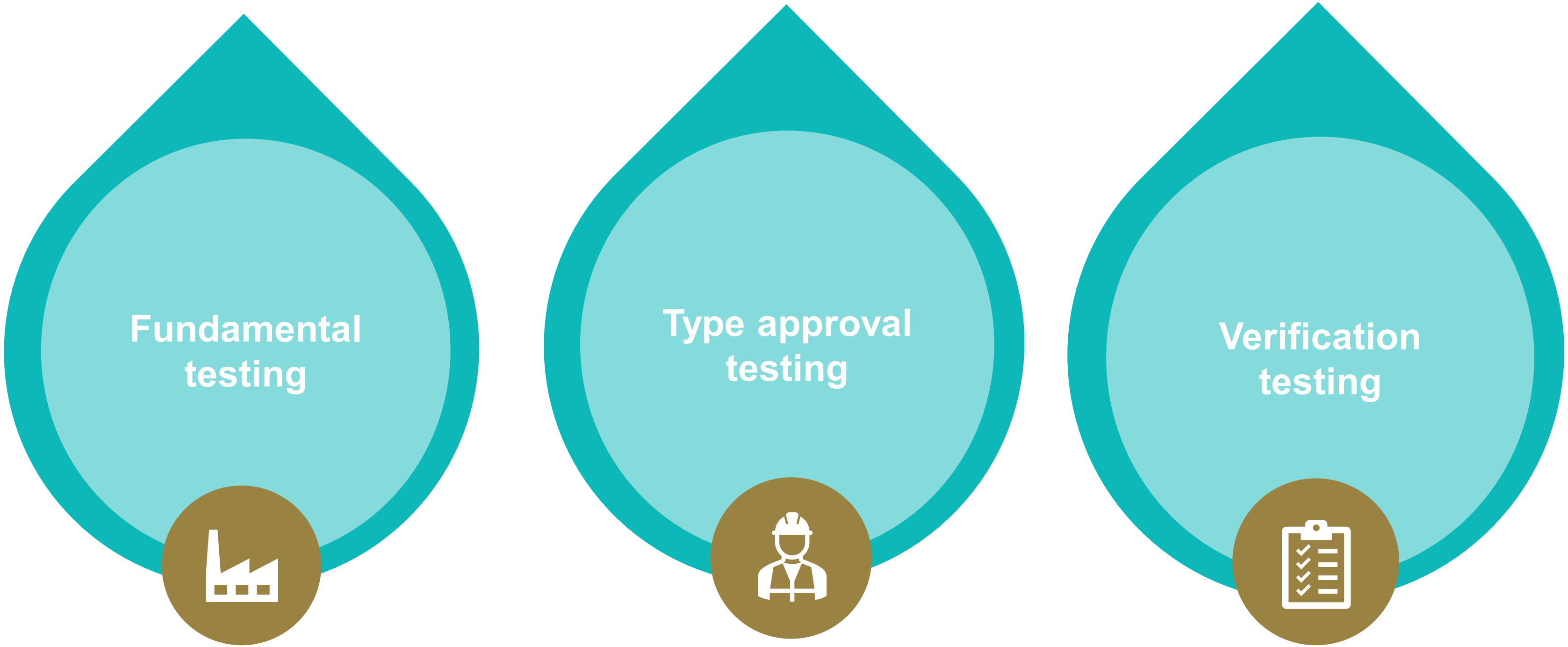
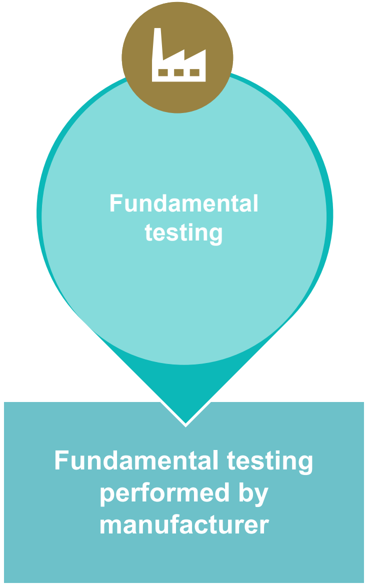
Classification of testing : Rubber and Foam

Classification of testing : Rubber and Foam

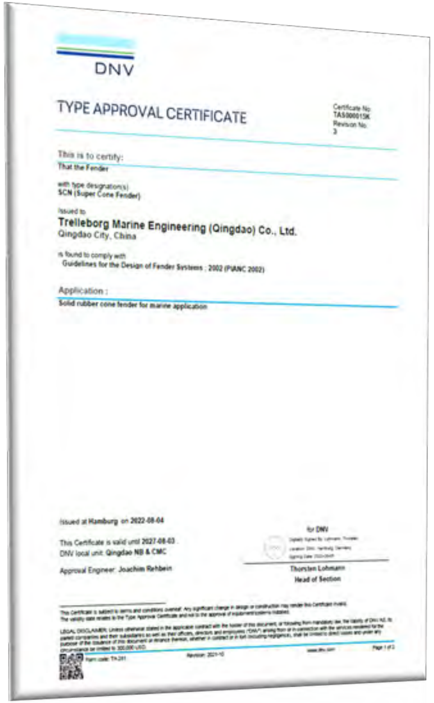


Fundamental Testing

- Base performance
- Creation of performance correction factors
- Durability test
- Chemical composition
- Physical properties



Type approval testing


DNV

TYPE APPROVAL CERTIFICATE

Certificate No: TAS000015K
Revision No: 3

This is to certify:
That the Fender

with type designation(s)
SCN (Super Cone Fender)

Issued to
Trelleborg Marine Engineering (Qingdao) Co., Ltd.
Qingdao City, China

is found to comply with
Guidelines for the Design of Fender Systems : 2002 (PIANC 2002)

Application :
Solid rubber cone fender for marine application

Issued at Hamburg on 2022-08-04

This Certificate is valid until 2027-08-03.
DNV local unit: Qingdao NB & CMC

Approval Engineer: Joachim Rehbein

for DNV

Thorsten Lohmann
Head of Section

1. Base performance (CV slow speed test data- **NO RPD data)**
2. Clear tables of Cv, Ct, and Cang (Performance correction factors)
3. Durability test (Min. 3000 cycles)
4. Chemical composition by TGA (Thermogravimetric analysis) results of compounds
5. Physical properties table

Type approval testing

Fundamental testing witnessed and verified by a 3rd party

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Verification testing

PIANC WG211 suggests 3 types of testing

Verification testing

- Mandatory tests
- Highly recommended tests
- Optional tests

Verification testing

The testing of commercial fenders to ascertain their adherence to the requirements

Verification Testing – Mandatory Testing

The absolute minimum for every project

Verification testing

Mandatory tests

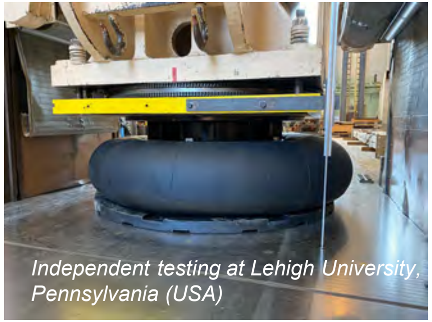
Mandatory tests cover:

- Verification of base performance
- Physical properties of rubber compound

Challenges:

- **Reliability of the performance data**
- **No link between the physical properties of the rubber compound tested and the actual fenders**
- **No link between the compound used for the project and the compound used for the type approval testing (correction factors, durability, etc.**

Verification Testing – Highly Recommended Testing



Independent testing at Lehigh University, Pennsylvania (USA)

Verification testing

Highly recommended tests

Highly recommended tests cover:

- Performance and physical properties testing witnessed by third party, using a third-party testing jig, or in a third-party testing facility
- Chemical composition or Thermogravimetric Analysis of rubber compound used for production
- TGA Analysis of samples from rubber fenders
- Skin thickness testing, and fender pull through tests for foam fenders

Challenges:

- **Still no guarantee on durability of the actual fender and the performance corrections factors**
- **No coverage of specific project requirements (cyclic conditions, resistance to shear)**

TGA testing

Two functions:

Traceability

- WG211 requirement (optional)
- Link between performance test result and physical properties
- Link between verification testing and type approval testing

Quality

- As per BS6394-1-4, Norwegian standard V431, Korean Standard KCS 64 45 10
- Restriction for non-reinforcement fillers such as ash, CaCo3, etc.
- Research by K. Shimizy et.at (2015) show a direct correlation between durability and CaCo3

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Verification Testing – Optional Testing

Verification testing

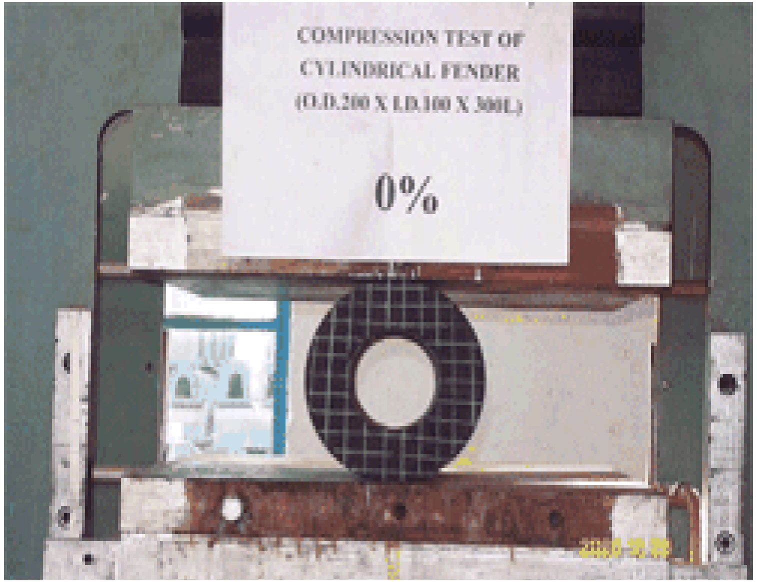
Optional tests

Optional Tests:

- Verification of factors
- Verification of durability tests
- Shear compression tests
- Fatigue test

Durability Testing

- The objective of this test is to simulate and assess the long-term fatigue performance of a fender within a condensed timeframe, providing insights into its longevity.
- WG33 specifies for 3,000 cycles of compression to its rated deflection in 150 seconds for a full cycle testing.
- WG211 recommends for a **minimum** of 3,000 cycle to its design deflection or more to suit specific project requirement
- A randomly chosen commercial fender is selected. If a full-size fender is not feasible, use a scaled-down model that adequately represents the commercial fender.
- The samples for TGA test of the specimen's body, before or upon completion of the durability test, must be collected by a third-party witness. The results should tally with the TGA of the fender body manufactured for the project.
- **Shear-compression test**: Repetitive deflections of the specimen is done to 50 % of the fender height while simultaneously applying shear forces causing deflections of 20-30 % of the fender height.
- **Fatigue testing** is highly recommended for fenders installed at exposed berths, high frequency berths, or between two permanently moored vessels. Test procedure has been recommended.



Acceptable criteria:
- No visible defects such as cracks.
- The loss of reaction force shall be less than 20 %
- The loss of energy absorption capacity shall be less than 20 %
- Height loss shall be less than 5 %.

Quality Verification & Quality Assurance

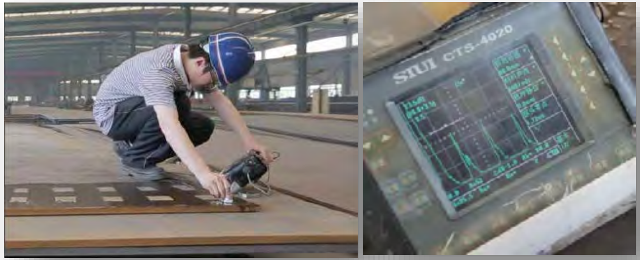
Quality Assurance (General)

- Supplier onboard qualification considering capabilities, quality, in-house testing, code of conduct & sustainability
- Annual supplier audits
- Random unannounced testing
- Dedicated QA/QC team visiting & checking suppliers' day to day

Quality Verification (Project Specific)

- Trelleborg in-house minimum projects standards (i.e. holiday and pull off testing paint)
- Translation client specification to works orders and ITP’s
- Following PIANC guidelines, and international standards /codes
- Project inspection following the ITP

Ultrasonic testing



Abrasion resistant test

Hardness test

Operation, Maintenance and Inspection

Installation & Commissioning

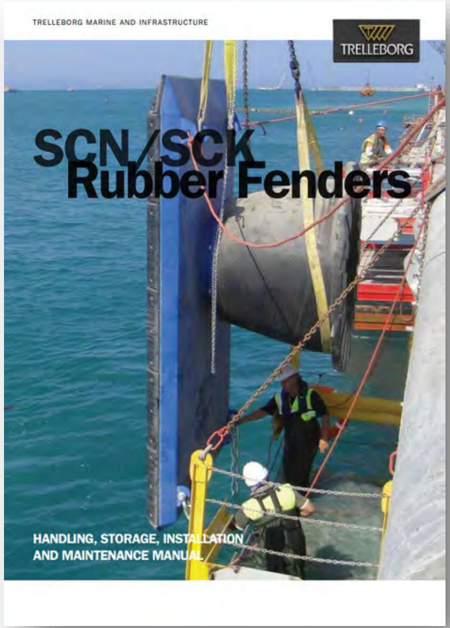
Correction installation essential for operational safety & longevity

Correct installation is important:

- Ensure the fender works as designed
- Reduce maintenance
- Increase lifetime of fender
- Operations safety

Commissioning and Installation Certification Services available

Refer to our detailed Handling, Storage, Installation & Maintenance Manuals



Inspection & Maintenance

Regular inspection reduces long term maintenance

- Inspection frequency – three levels of inspection recommend at 3, 6 and 12-month intervals

- Inspection of the following key fender components
  - Rubber Fender
  - UHMWPE Pads
  - Steel Front Panel
  - Chain Systems

- Reference material: Trelleborg Handling, Storage and Installation Manual

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Sustainability & Recycling

Sustainability

Marine fender systems - what can we do with our customers:

PIANC WG211 says: “The fender industry together with the end users as well as designers and other stakeholders should take the lead and challenge each other and co-operate to come to the most sustainable solution for their projects

Rubber

- Balance the blend NR / SBR
- Recycled carbon black
- Sustainable oils
- Superior quality fender improving durability and service life
- Inspection & Maintenance support extending the fender system service life

Steel

- Green steel with 70% reduced carbon footprint
- Improved design life due to superior materials and coating systems
- Inspection & Maintenance support extending the fender system service life

UHMWPE

- Biomass UHMPWE reducing the carbon footprint of the resin by 100%
- Recycling of old UHMWPE pads
- High quality virgin material extending service life

Logistics

- Eco delivery via 3rd party certified use of green fuel
- 65-95% reduction in carbon footprint

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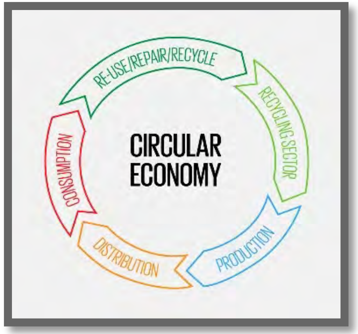
Recycling

Sustainable disposal of fenders at end-of-life

Current Situation

Current developments

Future



OUR JOURNEY

TRELLEBORG

Recycling Foam Fenders

- Our refurbishment technique, which may include repairing the existing outer layer or fitting a new skin over the existing foam core, is aimed at revitalizing these fenders. This not only extends their operational life but also improves safety, reduces waste, and maximizes the efficiency of port operations.
- By integrating International Renewable Energy Certificates (IRECs) into our operations at the Berryville facility, we ensure that our electricity consumption supports the generation of clean power.
- We also recycle our foam scrap externally, reinforcing the sustainability of our production processes.

Our revitalized foam fender, which was shipped from Canada to our Berryville, USA, manufacturing center for a unique refurbishment procedure.

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SESSION 5


A.D. 1885
PIANC
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NAVIGARE NECESSE
PIANC AU-NZ
The Australian Northern Chapter of the
World Association for Waterborne
Transport Infrastructure
WORKSHOP
NAVIGATING THROUGH PIANC
FENDER GUIDELINES 2024
(WG211) FOR DESIGNERS AND
ASSET OWNERS
WED 30 JUL 2025 | 12:30PM - 5:30PM
ENGINEERS AUSTRALIA
LEVEL 9/340 ADELAIDE ST
BRISBANE QLD
MEMBERS $30
NON-MEMBERS $50
STUDENTS FREE

Panel Discussion

Harvinder Singh

Principal Engineer

Jacobs

Sam Mazaheri

Chair, PIANC AU-NZ Northern Chapter (QLD & NT)

James Curl

Regional Director

Marine Fenders APAC

Adam Sellers

General Manager

Marine Fenders Oceania

Networking