TRELLEBORG

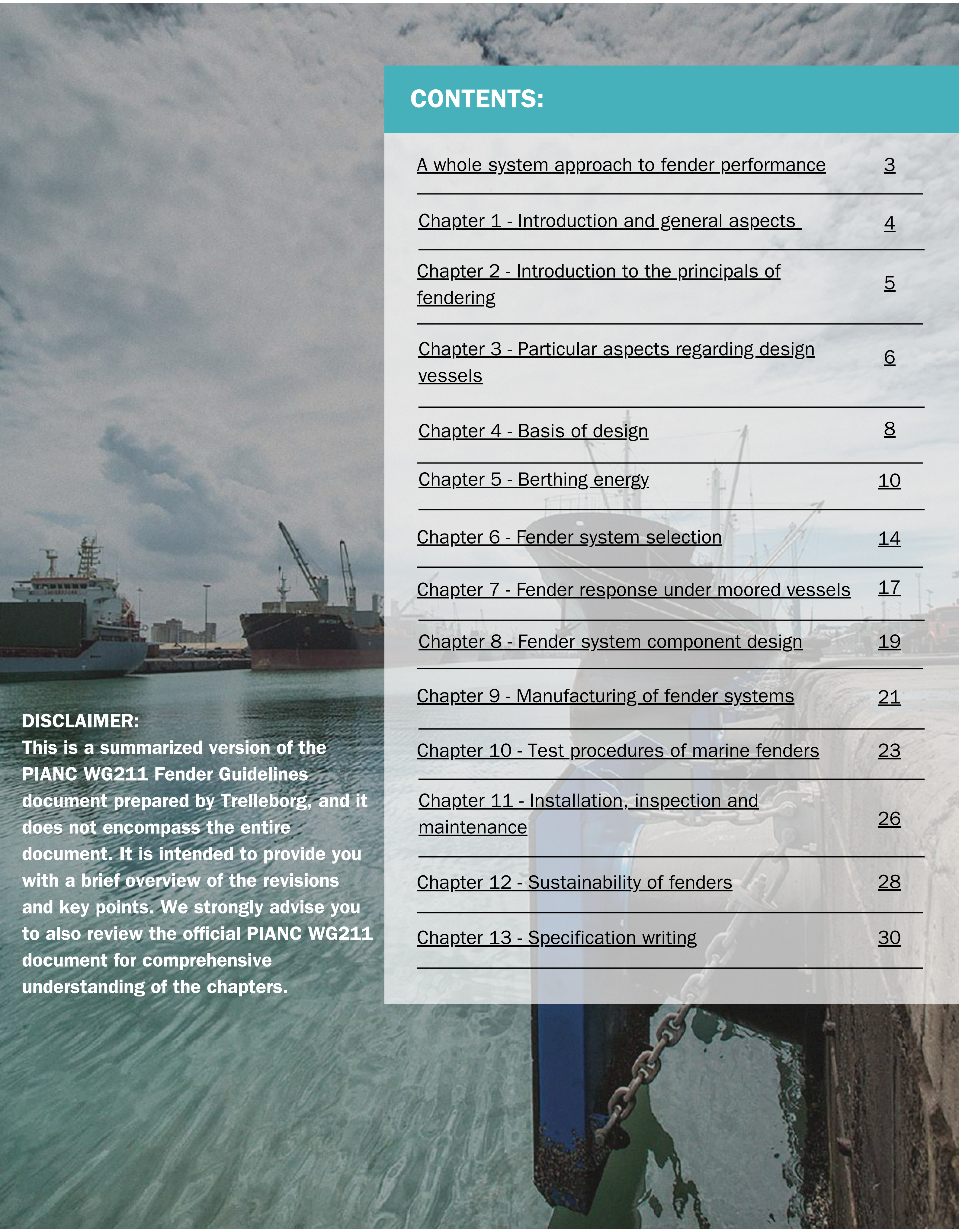
PIANC Fender Guidelines 2024

DOCUMENT OVERVIEW BY TRELLEBORG


PIANC
The World Association for Waterborne Transport Infrastructure

PIANC FENDER GUIDELINES 2024

MarCom Working Group Report N° 211 – 2024



CONTENTS:

DISCLAIMER:
This is a summarized version of the PIANC WG211 Fender Guidelines document prepared by Trelleborg, and it does not encompass the entire document. It is intended to provide you with a brief overview of the revisions and key points. We strongly advise you to also review the official PIANC WG211 document for comprehensive understanding of the chapters.

A whole system approach to fender performance

When it comes to fender systems, Trelleborg takes a whole system approach covering every aspect from application engineering to detailed design to rigorous quality control, along with installation and maintenance, to ensure fender reliability and performance. The new PIANC WG211 document covers this whole system approach in each of its 13 chapters.

Below is an overview of the essence of fender excellence, as well as how PIANC provides initial insights into its chapters within this framework. Chapters one 1 & 13 provide a general overview, while chapters 2-12 delve into the components of the whole system approach.

APPLICATION ENGINEERING

Trelleborg's highly-skilled application engineers across the globe is dedicated to engineering best-fit fender systems to better protect today's modern ports and terminals.

PIANC WG211 CHAPTERS 2-6

DETAILED DESIGN

Our dedicated center of excellence, designs meticulously engineered solutions and verifies their compliance with design standards, providing assurance that the system performs well in given site conditions throughout its design life.

PIANC WG211 CHAPTERS 7-8

MANUFACTURING AND TESTING

Our state-of-the-art manufacturing facilities are equipped with test presses that enable us to conduct comprehensive tests on a wide range of fenders. We also conduct independent quality and performance verification of all fender system components to optimize performance.

PIANC WG211 CHAPTERS 9-10

INSTALLATION AND MAINTENANCE

We provide complete support for fender system installation, operational and maintenance requirements including training manuals, on-site supervision and fender inspection services.

PIANC WG211 CHAPTERS 11-12

DOWNLOAD THE WHITEPAPER

Chapter one

INTRODUCTION AND GENERAL ASPECTS

The Working Group 211 final report represents a comprehensive revision of the PIANC MarCom WG33, 'Guidelines for Design of Fender Systems', and supersedes it and any other fender design and berthing guidance in other PIANC reports. Users should not mix the WG33 report with the WG211 report in their designs or specifications because the PIANC WG211 has adopted a different design approach than the PIANC WG33.

User specifications need a complete update and PIANC WG211 emphasizes the use of site-specific information.

There's a transition period until November 1, 2025, to align fender suppliers' catalogues with the new guidelines, requiring substantial type approval testing; however, designers can now start using the new guidelines.

This introduction chapter covers the following aspects:

- Background of the report
- Function & scope
- Climate change
- PIANC certified & PIANC type approval
- Contributors to the report
- Use of the guidelines

FUNCTION	SCOPE
▌Providing guidance for designing, manufacturing and testing of fender systems ▌Enhancing knowledge about fender systems ▌Guiding through the steps from initial design stage up to testing and installation	▌Applies to seagoing vessels, primary tug assisted or equipped with thrusters ▌WG211 is for berthing, not collisions or protection structures ▌The design approach is for new structures as older structures may have conservative partial safety factors ▌Guidance for assessing existing structures

Climate change impact

PIANC WG211 recognizes climate change as a key factor influencing berthing conditions and fender system design. The report suggests ways to make a positive impact through design (Chapter 5) and the longevity of the fender system, reducing the carbon footprint (Chapter 12).

PIANC certified fenders and PIANC type approval

The PIANC name has been misused by some fender suppliers by false claims such as "PIANC Certified Fenders." However, that is not the case as PIANC is not a certifying body. PIANC WG211 addresses this in this chapter and explains that fenders can be designed, produced, and tested in accordance with the new guidelines.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg is dedicated to following the guidelines outlined in the latest PIANC WG211 document, and we will promptly update all our catalogs accordingly. We provide complete transparency regarding third-party type approval as per PIANC WG211. Our commitment extends to educating the industry about all aspects of PIANC WG211.

Chapter two

INTRODUCTION TO THE PRINCIPALS OF FENDERING

This chapter gives an overview of various types of fenders and fender systems used globally, as well as general fender selection and design approach, providing insights on cone, cell, arch, cylindrical, MV elements, foam and pneumatic fenders, complete with illustrations, performance curves, and information on dimensions and sizes. Additionally, engineered solutions like parallel motion, pivot, and rolling fenders, as well as ship-to-ship considerations, are also discussed.

> This chapter is the starting point for less experienced engineers and provides valuable insights on the various types of fenders.

The table below, extracted from PIANC WG211, offers an overview of the various fender types and their performance ranges.

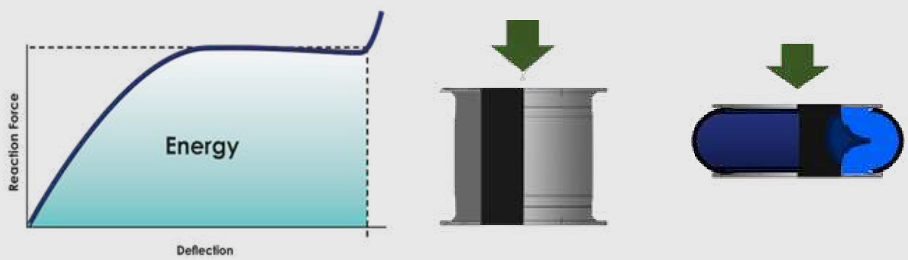
Cone Fenders	Cell Fenders	Element/Leg Fenders	Arch Fenders	Foam Fenders	Pneumatic Fenders
Size: h_f 300 - 2500	Size: h_f 400 - 3000	Size: h_f 250 - 2000	Size: h_f 150 - 1000	Size: D 700 - 4200 L 1500 - 8500	Size: D 500 - 4500 L 1000 - 12000
E_A: ~ 10 - 9500	E_A: ~ 10 - 9800	E_A: ~ 10 - 1300	E_A: ~ 5 - 450	E_A: ~ 30 - 9000	E_A: ~ 6 - 9050
R_F: ~ 55 – 7200	R_F: ~ 50 - 8850	R_F: ~ 80 - 1750	R_F: ~ 90 - 1050	R_F: ~ 130 - 8500	R_F: ~ 65 - 10500
		Performance values for single unit of 1,000 mm length	*Performance values for single unit of 1,000 mm length*		

All sizes are in mm | EA in kNm | RF in kN | Shapes might differ from manufacturer to manufacturer

PIANC WG211 Table 2-1: Typical fender types

Fender efficiency and fender selection

PIANC comprehensively explains how fenders function and absorb berthing energy. There are primarily two types of fenders: Buckling and side-loaded, each possessing distinct characteristics. PIANC WG211 aims to provide the reader with a thorough understanding of the various types of fenders, enabling designers to make informed choices regarding fender selection. Below is an illustration from PIANC WG211 demonstrating the operation of a buckling type fender.



PIANC WG211 Figure 2-1: Typical buckling fender deflection curve

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg remains dedicated to assisting our clients in choosing the right fender. We have also developed online tools and brochures to guide our clients in the fender selection process which will be updated shortly to reflect the changes in WG211. Our in-house manufacturing facilities enable us to produce a wide range of fenders, including rubber, foam, and pneumatic options, as well as the largest selection of fenders, including intermediate sizes up to SCN2500 and SCK3000.

Chapter three

PARTICULAR ASPECTS REGARDING DESIGN VESSELS

This chapter focuses on the specific aspects of designing vessels and their relevance to fender design. It discusses the importance of understanding the characteristics of the design vessel, as provided by the customer, to guide the fender design process.

It also provides information on ship types and hull shapes relevant to the design of fenders and should be read in conjunction with PIANC WG235: Ship Dimensions and Data for Design of Marine Infrastructure (PIANC WG235, 2022).

This chapter is essential to work with accurate vessel data.

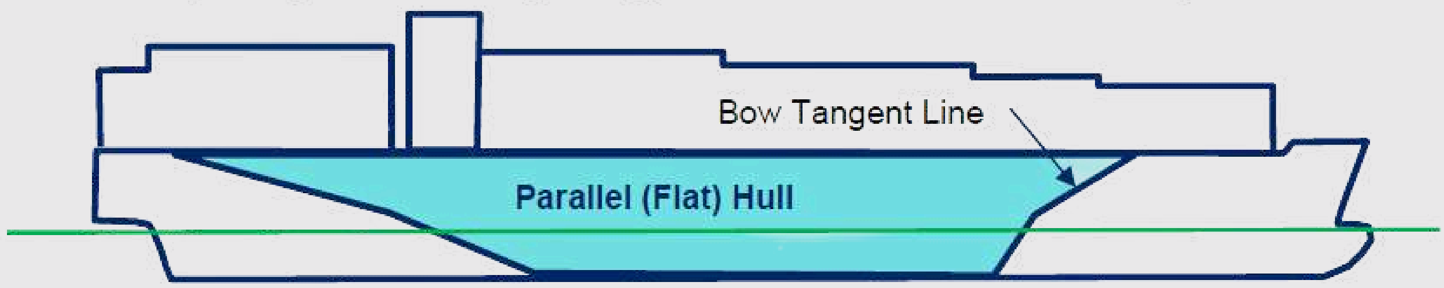
There are 3 main sections detailed in this chapter by PIANC WG211:

- Vessel Characteristics
- Displacement
- Influence of Vessel Hull Characteristics on Fender Design

VESSEL CHARACTERISTICS

This section offers practical guidance to designers on vessel characteristics relevant to designing fendering systems, in addition to the WG235 report. PIANC WG211 covers all ocean going vessels such as Dry Bulk & Ore Carriers, Cruise Vessels, RoRo, RoPax and Vehicle (Car) Carriers, Tankers, Gas Carriers (LPG and LNG), General Cargo, Refrigerated Cargo and Livestock Carriers, Passenger Ferries, and Fishing Vessels.

For example, it discusses how the relatively short parallel body of container vessels impacts the berthing energy and thus fender design. Refer to Figure 3-1.



PIANC WG211 Figure 3-1: Parallel mid-body of a typical container vessel hull

DISPLACEMENT

Vessel owners often overlook providing information about displacement in their specifications, as they focus more on parameters like DWT. However, as designers, we should consider displacement to be an important factor.

It's recommended to read the relevant information when needed. I.e. study the container vessel information when working on a container berth. The information in this chapter will help to optmize the design and reduce costs and improve the operations.

PIANC WG211 provides 3 methods to estimate the displacement:

I. Full laden displacement as listed in WG235
II. Calculate with the following formula:

$$M = L_{BP} . B . D . \rho_w . C_b$$

Where

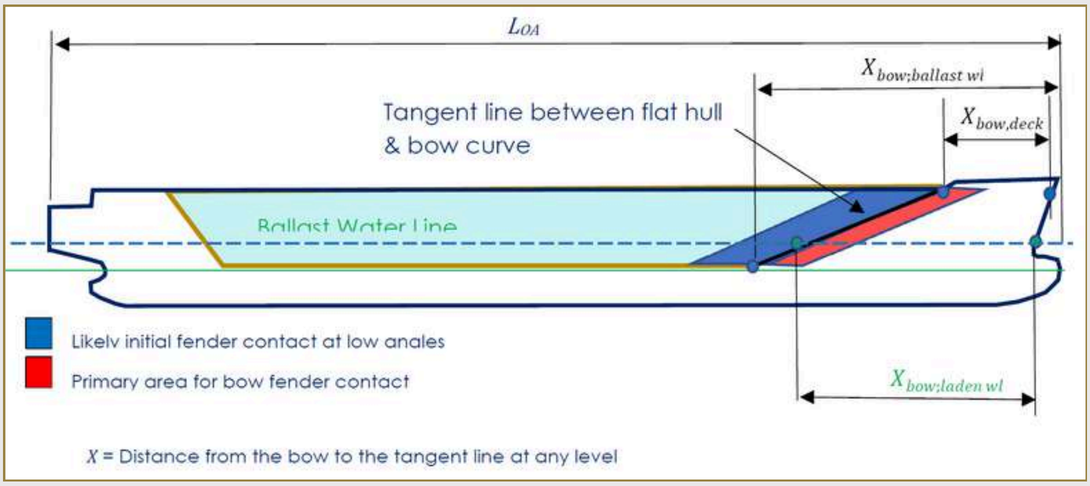
M	*Mass equivalent to the water displacement of berthing vessel [tonnes]*
L_{BP}	*Length between perpendiculars [m]*
B	*Beam of vessel [m]*
D	*Draught of vessel at midships [m]*
ρ_w	*Density of water (1.025 typical for seawater) [tonne / m^3]*
C_b	*Block coefficient of vessel*

III. Relationship between displacement and capacity (DWT)

INFLUENCE OF VESSEL HULL CHARACTERISTICS ON FENDER DESIGN

This section provides insights into assessing vessel hull configurations and their impact on the clearance between the vessel and the structure, the engagement with the fender or multiple fenders, and the initial point of contact with the fender.

Figure 3-2 in this section PIANC WG211 defines key zones of a vessel hull with respect to fender contact.



PIANC WG211 Figure 3.2: Fender contact zones on vessel hull at low berthing angles

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg can provide support in the vessel assessments, leading to more precise fender design and cost-effective investments. Our online tools include WG235 data to help users avoid common design mistakes and to better consider complex hull shapes in multiple fender contact.

Chapter four

BASIS OF DESIGN

This chapter outlines the key factors to consider when designing a fender system, serving as a guide for the design process and a template for creating a comprehensive basis of a design document. The design of the fender system should serve the primary functions outlined in Chapter 2 and meet both functional and operational requirements. It's essential to give the design of a fender system the same level of consideration as any other element of the structure of which it is a part of. The fender should be designed considering the following 6 criteria:

Functional requirements :

The functional requirements, in essence, revolve around elucidating the fundamental purpose of the fender.

Operational requirements:

Operational considerations have substantial influence over fender system selection and design. This section provides guidance on the key operational aspects that need to be considered.

Assessment of site conditions:

To establish the factors influencing fender system design, it's essential to gather comprehensive data about the berth's configuration and location. These factors impact aspects like fender system loading, durability, and material selection. PIANC WG211 provides guidance on the key site conditions to be considererd.

Assessment of the design criteria:

After evaluating the functional and operational requirements and considering site conditions, the design criteria used to calculate berthing energy and the selection of the fender system can be established.

Operation and maintenance:

The design life of a fender system is typically shorter than that of the marine structures it interacts with. To ensure its continuous functionality during its design life, a regular maintenance and inspection plan is crucial, typically involving annual visual inspections. PIANC WG211 provides guidance on how this is addressed.

Assessment of acceptable reliability levels:

A crucial aspect of designing a fender system is understanding the consequence of failure of a fender system and its impact. Understanding these failure consequences is vital, as higher consequences typically necessitate greater reliability. In some cases, a single fender failure might not result in significant economic impacts, while in others, it could lead to major accidents.

Table 4-1 PIANC WG211 provides detailed examples of fender systems for different consequence classes, with class A and class B being the most common for marine structures. The port authorities or terminals, should choose the consequence class based on appropriate input, as detailed in Chapter 13 of PIANC WG211.

CLASS	EXAMPLE OF FENDER SYSTEMS
A	**Fenders installed on a marine structure within a terminal or port with functional redundancy and a limited number of people at risk.** If one fender were to fail, it is not likely that it would lead to the unavailability of the berth or widespread damage to the marine facility, assuming that there is sufficient redundancy with additional berths. For instance, this could include a continuous earth-retaining quay wall or a dolphin berth equipped with more than two redundant berthing (breasting) dolphins, or marine facilities that have multiple berths with similar capabilities.
B	**Fenders installed on a marine structure without functional redundancy.** If the fender system fails, the berth will most likely be unavailable, leaving no alternate options. A single berth with two berthing (breasting) dolphins is an example.
C	**Fenders installed on marine structures, positioned at locations where failure of the fender system is likely to endanger public lives.** Fenders installed on a marine structure where failure of the fender system is likely to close the berth and cause significant economic losses. Examples include critical floating powerplants or floating storage regasification units that are prohibited from operating due to fender failure and lack sufficient backup methods to resume operations.
D	**Fenders installed on marine structure where failure 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 like critical installations such as essential powerplants or floating storage regassification units that are prohibited from operating due to fender damage with no backup measures available to resume operations.

The selection of the right consequence class is important as it impacts:
1) The partial energy factor PIANC WG211 Chapter 5
2) The partial safety factor for multiple fender contact PIANC WG211 Chapter 6
3) Partial load factor for fender system accessories design PIANC WG211 Chapter 6

This ultimately impacts design berthing energy, fender selection and fender panel calculation.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg can support you in the assessment of all relevant design requirements. We are well-equipped to help you not only comprehend the relevance of the consequence class but also to comprehensively determine the suitable consequence class to determine the optimum fender design to be incorporated.

Chapter five

BERTHING ENERGY

PIANC WG211 chapter 5 provides guidance on calculating the berthing energy of a vessel that the fender system should absorb. PIANC WG211 provides clear steps in the process of calculating the energy.

1 Berthing Maneuvers & Navigation Conditions

2 Kinetic Energy

3 Displacement

4 Berthing Energy

5 Berthing Angle

6 Eccentricity Factor

7 Added Mass Factor

8 Partial Energy Factor

1. BERTHING MANEUVERS & NAVIGATION CONDITIONS

PIANC WG211 considers the various berthing maneuvers as they occur in ports: Alongside Berthing and End Berthing.

New in PIANC WG211 compared to the old PIANC WG33 is the introduction of Navigation Conditions. PIANC WG211 considered the following navigation conditions:

- Favourable
- Moderate
- Unfavourable

PIANC Working Group 211 offers detailed descriptions of these navigation conditions, assisting designers in selecting the right navigation conditions. This is critical in determining the berthing energy process as the navigation conditions could impact the berthing energy and the Partial Energy Factor.

2. KINETIC ENERGY OF A BERTHING VESSEL

PIANC WG211 introduces a new terminology for Berthing Energy:

Characteristic Berthing Energy:

This is the calculated berthing energy based on characterestic conditions and based on the following formula (PIANC WG211, equation 5-4):

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

Design Berthing Energy:

This is the berthing energy used for the design of the fender system and including the Partial Energy Factor that counts for uncertainty in the berthing energy calculation

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

3. DISPLACEMENT:

The characteristic displacement (M_C) should be considered for the berthing energy calculation which is defined as the largest operational displacement of the design vessel.

PIANC WG211 recommends using site specific information but when not available the recommendations of WG235 can be considered. Additionally, PIANC WG211 Chapter 3 Section 2 provides guidance on determining the vessel’s displacement.

4. BERTHING VELOCITY:

The berthing velocity is the dominant factor in determining the berthing energy of a vessel. The berthing velocity is defined by PIANC WG211 as the vessel’s approach velocity at first contact with the fender system.

PIANC WG211 recommends that the berthing velocity should be provided by the asset owner. Furthermore, PIANC WG211 suggests that site-specific information and experience are used. When site-specific information is not available for a new design, table 5-3 can be used for the transverse velocity and table 5-4 for the longitudinal velocity applicable for end berthing’s.

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]

PIANC WG211 Table 5-3 : Characteristic berthing velocity in the absence of site-specific information

5. BERTHING ANGLE:

The berthing angle is the angle between the heading of the vessel and the berthing line. Again, PIANC WG211 recommends using site specific information but if not available PIANC WG211 provides guidance to determine the berthing angles considering the method of approach, use of tugs and the use of thrusters (PIANC WG211 table 5-5).

PIANC WG211 considers two types of berthing angles:

Characteristic berthing energy → Used for determining the berthing energy

Incidental berthing energy → Used to verify the safe clearance between the vessel hull and the structure

6. ECCENTRICITY FACTOR:

Some of the berthing energy will dissipate due to yawing of the vessel. The eccentricity factor (C_e) will account for this in the berthing energy calculation. The eccentricity is calculated with the equation:

$$C_e = \frac{K^2 + r_F^2 \cos^2(\emptyset)}{K^2 + r_F^2}$$

The point of impact (r_F in above equation) is critical in determining the C_e factor. PIANC WG211 provides various methods to determine r_F and these methods depend on engagement of multiple fenders or single fender contact only and the availability of information on the vessels hull. Furthermore, PIANC WG211 provides basic guidance on the C_e factor based on fifth point, quarter point, third point and mid ship impact.

7. ADDED MASS FACTOR:

A vessel in motion is subject to a range of hydrodynamic forces, such as drag forces, due to the mass of the water that "moves" with the vessel. This force is known as added mass and is considered in the berthing energy calculation as the Added Mass Factor (C_m). PIANC WG211 considers only one method for alongside berthing to determine the Added Mass Factor which is based on the PIANC WG33 method and considers the under-keel clearance of the vessel and the vessels draught. Furthermore, PIANC WG211 provides guidance for determining the Added Mass Factor for end berthing's.

8. PARTIAL ENERGY FACTOR:

In simple terms the Partial Energy Factor is the old "Abnormal berthing factor"

The Partial Energy Factor (γ_E) accounts for the uncertainty in the berthing energy calculation.

With the Partial Energy Factor the Design Berthing Energy $E_{K,D}$ can be determined by applying it on the Characteristic Berthing Energy $E_{K,C}$.

Although the Partial Energy Factor could be compared with the "Abnormal berthing factor" as per PIANC WG33, the method to determine this factor is very different. Where PIANC WG33 considered the type of vessel and vessel size only (PIANC WG33 Table 4.2.5), PIANC WG211 considers multiple factors:

- Consequence class (reference to PIANC WG211 chapter 4)
- Navigation conditions
- Variations in displacement
- Single or multiple fender contact
- Berthing frequency
- Pilot assistance
- Site specific information

PIANC WG211 provides direction on how to determine the Reference Partial Energy Factor $\gamma_{E,ref}$ (tables of PIANC WG211 5-8 to 5-10) which considers a berthing frequency of 100 berthing's per year. The above-mentioned factors are considered in these table and corrected as needed, i.e. in the case of a different berthing frequency.

The Partial Energy Factor is calculated as follows:

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

Where :

$\gamma_{E,ref}$	Reference partial energy factor for 100 berthing's per year
γ_n	Correction factor for alternative annual berthing frequencies
γ_p	Correction factor for berthing without pilot assistance
γ_c	Correction factor for correlations between design variables

SHIP-TO-SHIP BERTHING

PIANC WG211 also provides guidance for designing fenders in ship-to-ship applications that are not covered by OCIMF STS Transfer Guidelines.

For ship-to-ship applications where both vessels are free-floating, the berthing energy calculations should account for the mass of both vessels.

Characteristic berthing energy

$$E_{k,c} = E_{sts,c} = \left(\frac{1}{2} \cdot M_{sts,c} V_{sts,c}^2\right) \cdot C_{sts,e}$$

Characteristic mass

$$M_{sts,c} = \frac{M_1 C_{m1} M_2 C_{m2}}{M_1 C_{m1} + M_2 C_{m2}}$$

Furthermore, PIANC WG211 provides guidance on determining the Characteristic Berthing Velocity the "Relative Approach Velocity" or "Closing Velocity" as well as determining the Eccentricity Factor.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg is taking a proactive leadership role in developing berthing energy calculation tools. Trelleborg can already assist you with berthing energy calculations as per the new PIANC WG211 supported by our internal tools. Soon, our online berthing energy calculation tool will adopt the PIANC WG211 and be available for our clients to perform their own berthing energy calculations and fender selection in accordance with the new guidelines. Trelleborg will host educational webinars and lunch and learn sessions (Please consult Trelleborg if you are interested in organizing one in your organization).

Trelleborg provides technology such as portable piloting units, SmartFender, and docking aid systems to collect site data, allowing our customers to optimize fender design for a safer port. Overall, Trelleborg is actively driving advancements in berthing energy calculations and fostering knowledge sharing and technology development in this domain.

Chapter six

FENDER SYSTEM SELECTION

This chapter outlines the fender selection process, providing background information on all critical elements that should be considered when selecting a fender system.

The role of the designer in the fender selection process is clearly outlined.

PIANC WG211 says that
"The selection of a fender system deserves as much attention as the design of any other element of the structure of which it is a part."

FENDER SELECTION OVERVIEW

PIANC WG211 provides a clear overview of the fender selection process in figure 6.1. The key steps in this process are:

1. Requirements	Identify the functional and operational requirements as well as the site conditions and design criteria
2. Type of Fender	Identify the type of fender that is likely to satisfy the project requirements
3. Base Performance	Identify the catalog performance of the fender under specific testing conditions. Previously known as CV performance (PIANC WG33)
4. Characteristic Performance	Identify the performance of the fender in actual site conditions, including all performance correction factors
5. Design Performance	Identify the performance by applying the Partial Safety factors (Which is covering the manufacturing tolerances)
6. Verification	Verifying that Design performance meets the Design Energy and all other project requirements

PIANC WG211 also introduces Pre-Set Design Criteria. The pre-set design criteria presents the fender performance at specific design conditions which are closer to site conditions than the base performance but not as specific as the characteristic performance. The preset design criteria allows the designer to quickly select a preliminary fender based on the Pre-set design criteria as published in the fender supplier's catalog. However, this is not intended to be used for the final design – for the final design the characteristic and the design performance should be used.

FENDER SYSTEM SELECTION

PIANC WG211 offers guidance on the application of fender systems related to various types of vessels and marine applications. For example, it recommends specific types of fenders that can be used in conjunction with belted vessels, in ice zones, for lock entries, and various other scenarios.

PIANC WG211 provides guidance on various key factors to consider when selecting a fender system.
The factors are:

- Bow Radius
- Bow Flare
- Fender System Pitch
- Single fender contact
- Multiple fender contact
- Vessel Hull Structure
- Vessel Belting
- Double Hull Contact
- Type of Support Structure
- Flexible Dolphins
- Fender System Elevation
- Pneumatic and Foam Fenders
- Number and Size of Fenders
- Shear of Fenders
- Submerged Fenders
- Fender Orientation
- Aging Effects on Fenders
- Non-Marking Fenders
- Mooring Analysis
- Permanent Mooring

PIANC WG211 provides detailed guidance on each of these factors.

BASE FENDER PERFORMANCE:

The base fender performance is the fender performance at standard testing conditions at slow Constant Velocity (CV) compression testing method (reference is made to PIANC WG211 chapter 10). This is the fender performance as tested and prior to applying any Correction Factors.

CORRECTION FACTORS & CHARACTERISTIC PERFORMANCE

The Base performance is the performance of the fender under testing conditions however, it must be adjusted to reflect the site's actual conditions. This is taken care of by the Correction factors. PIANC WG211 takes into account the following correction factors:

- Velocity Factor (C_v)
- Temperature Factor (C_t)
- Angular Factor (C_{ang})
- Multiple Fender Contact Factor (C_{mult})

Applying the correction factors to the fender base performance results in the fender characteristic performance.

Determining Fender Design Performance

The fender design performance ($E_{f,d}$) is derived by applying partial resistance factors of safety to the characteristic performance values.

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

The partial resistance factors γ_m covers:

i.The single fender partial resistance factor γ_f
ii.The multiple fender partial resistance factor γ_{mult}

In this section, PIANC WG211 explains how to determine these factors and how they should be considered for buckling and side-loaded fenders. It also explains how the Fender Design Performance should be considered for the fender component design, the hull structure verification and the supporting structure.

The below table 6-3 from PIANC WG211 provides the guidance to determining the single fender partial resistance factor γ_f .

Performance tolerance	γ_f factor for all consequence classes	Typical example types of fender system
+/- 10%	1.10	Cone, cell, arch, element and cylindrical (wrapped) fenders
+/- 15%	1.15	Foam fenders
+/- 20%	1.20	Cylindrical (extruded), extruded, composite and shear fenders, wheel and roller fenders
Reference ISO17357-1	1.00	Pneumatic fenders [a]

a) γ_f = 1.0 for the calculation of the Design Berthing Energy according to ISO 17357-1. Pneumatic fender performance is given as a guaranteed value, hence no material factor needed.

PIANC WG211 Table 6-3 : Partial resistance factor γ_f related to the performance of a single fender

HULL PRESSURE

While absorbing the berthing energy of a vessel, the fender will exert a reaction force on the vessel (as well as the supporting structure). These forces should not exceed the vessel hull structural capacity.

PIANC WG211 provides guidance on the vessel hull structure and PIANC WG211 table 6-6 considers the maximum ultimate hull pressure as well as the maximum ultimate fender reaction force on the hull.

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)

PIANC WG211 Table 6-6 : Typical values of hull pressure capacity

SHIP-TO-SHIP FENDERING

The OCIMF MEG4 covers the fender selection for offshore fendering for ship-to-ship transfers. PIANC WG211 covers nearshore transfers and FSRU's.

Table 6-7 of the PIANC WG211 provides recommendations on the fender arrangement for various types based on combined mass coefficient (M_{cv}).

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg is actively working to align with the latest guidelines by updating the marketing materials, including brochures, and enhancing the Fender Application Design Manual (FADM) and other online tools. We recognize the complexity of scenarios involving multiple fender contacts and are developing supporting tools to streamline the assessment process. Moreover, Trelleborg continues to promote the use of performance correction factors in fender design and selection. We are also committed to educating and raising awareness in the industry.

Chapter seven

FENDER RESPONSE UNDER MOORED CONDITIONS

This chapter outlines the design considerations that are applicable for fender systems that are required to accommodate moored vessels. It's important to address these considerations because, although berthing maneuvers can be controlled, the mooring conditions can transmit greater forces on the fender system.

Whilst berthing can be controlled, the mooring conditions may transmit higher loads into the fender system.

PIANC WG211 suggests that the suitability for moored vessels, in particular the 'lean-on' mooring loads need to be assessed for fender systems. This assessment includes factors like waves, wind, currents, and loads from passing vessels, as well as extreme conditions like hurricanes and squalls and the impact of pre-tensioned mooring lines.

PIANC WG211 SUGGESTS 4 CRITICAL ELEMENTS TO BE CONSIDERED IN MOORED CONDITIONS:

I. FENDER DESIGN FOR MOORED VESSELS

This section explains that the selection of a fender should consider not only the berthing energy but also a range of conditions acting on the vessel.

II. CHARACTERIZATIONS OF VESSEL AND BERTH CONFIGURATION

Here PIANC suggests that to evaluate a fender system's performance for a moored vessel, it is crucial to understand the specific characteristics of the vessel and berth, as well as the probable mooring configurations. This evaluation should consider the parameters for fender contact, such as the size and position of the vessel's parallel mid-body, the exact layout of the terminal geometry, all potential mooring positions and configurations, and any potential interferences with the fender system.

III. MOORING ANALYSIS

A mooring analysis involves assessing how a moored vessel reacts to environmental forces like winds and waves at a berth. PIANC WG211 details how mooring assessment can be utilized in evaluating fender systems.

IV. CREEP AND FATIGUE ASSESSMENT FOR DYNAMIC MOORING SITUATIONS

Fender fatigue analysis is typically not required in protected ports. However, in exposed locations, the effects of constant swells or frequent and strong gusty wind should be carefully considered.

* These conditions are substantially different from the fender testing conditions
* The effect of fatigue and creep on fenders must be assessed. When identified that the local conditions at the berth may be of relevance for fatigue fenders, an assessment must be performed.

PIANC WG211 addresses the above in detail in this section. This is a new design consideration that was not addressed in PIANC WG33.

PIANC WG211 suggests that when selecting fenders for dynamic mooring situations, the following factors should be carefully considered.

- Fatigue in fenders - Fatigue in fenders refers to the progressive damage in the fender body material caused by cyclic loading, potentially leading to fender failure.
- Fatigue life - Fatigue life is the maximum number of loading cycles a fender element can withstand before it fails.
- Creep in fenders - Creep in fenders is the permanent deformation that occurs after loading. In rubber and foam-filled fenders, creep results from different phenomena, with foam-filled fenders needing more time to recover after each load cycle. For all types of fenders, there is a significant relationship between creep and fatigue damage, as creep amplifies the effects of cyclic loading.

PIANC WG211 states that the impact of fatigue on fenders varies based on their type and material. It offers guidance on fatigue damage for rubber, foam, and pneumatic fenders.

PIANC WG211 explains that durability tests for fenders usually involve repeated compressions with a cycle duration of 150 seconds. However, environmental loads can cause compressions at a much shorter cycle period, leading to a higher rate of heat transfer within the fender. This increased heat can cause the rubber to soften, resulting in larger deflections and reducing the fender's ability to rebound between cycles.

Designers must consider fatigue effects and seek manufacturer advice when assessing fatigue, while manufacturers are responsible for defining fatigue limits when there's no published data.

PIANC WG211 suggests that in the absence of project-specific limits provided by manufacturers or other reliable sources, the following limits are recommended for buckling fenders:

1. Buckling fenders should be chosen with care to ensure they don't buckle due to creep after prolonged static loads from continuous wind or currents. They should also withstand repetitive ship motions without exceeding the peak of the reaction force.
2. Creep limit: Under design conditions, the continuous load should not surpass 40% to 50% of the design load, equivalent to 5% - 10% deflection.
3. Fatigue limit: The maximum cyclic deflections under design conditions should not exceed the buckling limit, which is the peak of the performance curve.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg's focus on innovative product design and high-quality compound materials significantly enhances the fatigue performance of fenders. We are committed to creating awareness in the industry by developing technical papers, providing both internal and external training, offering supporting tools, and facilitating data requests. Trelleborg fenders have passed rigorous durability tests (110K cycles at 35% and 50K at 50%) for SCN, and similar tests have been conducted for PNE fenders as well which demonstrates our commitment to producing highly durable products.

Trelleborg is actively engaged in further research, recognizing the need for more testing data to support fatigue design and fender selection.

Chapter eight

FENDER SYSTEM COMPONENT DESIGN

PIANC WG211 states that when designing fender systems, it's crucial to pay attention to the details of the fender panel, chains, UHMW-PE pads, and fixings to ensure both efficiency and robustness. These components must be integrated into the overall berth design, as the berth structure must be capable of accommodating the fender system and all related elements like chains and anchors. PIANC WG211 outlines the various factors to be taken into consideration in the design process for fender system components that include:

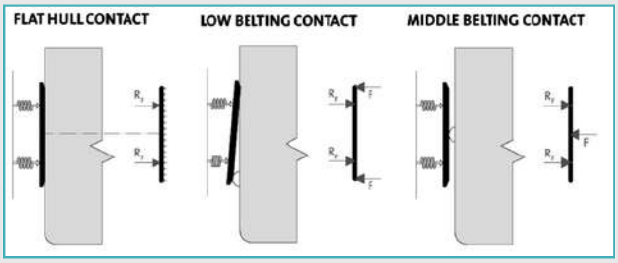
- Fender Panel Design
- Accessories Design
- Whole Life Considerations
- Special Design Considerations

FENDER PANEL DESIGN

PIANC WG211 discusses the importance of the fender panel and its design, highlighting how factors such as maximum hull pressure, hull curvature, and vessel projections (belting) influence fender panel design.

Load Cases and Structural Analysis

PIANC WG211 highlights typical design cases of fender contact with the vessel hull profile in figure 8.1. It states that the longevity and effectiveness of a fender panel design largely depend on accurately identifying and defining all potential load cases that could occur throughout the system's life cycle. Additionally, the document emphasizes the importance of design calculations that should consider bending, shear, local buckling, and crushing effects on the steel panels and fender frames, to ensure robust and reliable fender systems.

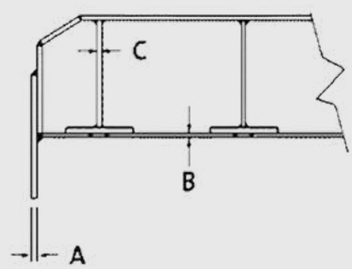


PIANC WG211 Figure 8.1: Typical design cases of fender contact with vessel hull profile

Fender panel internal structure

PIANC WG211 outlines the typical range of panel weights and intended uses. It talks about the two types of fender panel structural forms of construction the 'closed' and 'open' box. In figure 8.2 it also provides recommended minimum thickness for steel section in fender panels.

Plates exposed on two surfaces:
≥ 12 mm (A)
Plates exposed on one surface:
≥ 9-10 mm (B)
Internal members (not exposed):
≥ 8 mm (C)



PIANC WG211 Figure 8.2: Recommended minimum thicknesses for steel in fender panels

Chamfers

PIANC WG211 outlines factors that lead to the direct application of vertical or horizontal loads to the perimeter of the panel, potentially compromising the durability of the fender system by introducing destructive shear forces to the rubber unit, which it is not designed to resist. It further states that to minimize potential damage, fender panel design should include edge chamfers or bevels around the panel edges.

Panel size and position

PIANC WG211 outlines the requirements for determining the appropriate width, height, thickness, and position of the fender on a panel, which are critical for vessel safety and operational efficiency. Additionally, PIANC WG211 emphasizes the importance of considering factors such as tidal range, wind force, and tidal currents, which influence the dimensions and positioning of the fender system.

ACCESSORIES DESIGN

Chain system design

PIANC WG211 addresses the design of chain systems, which play a crucial role in maintaining panel alignment and ensuring that fenders compress optimally at nearly zero degrees to maximize energy absorption. This section covers various types and positions of chains—weight, shear and tension—and their design parameter. It also discusses design considerations when choosing chains for cylindrical, foam and pneumatic fenders.

Weight chains	support the fender system and prevent excessive drooping of the system caused by self-weight forces. They may also resist vertical downwards shear forces caused by vessel movements or changing draught.
Tension chains	Restrict tension forces in on the fender rubber. Correct location can optimise the deflection geometry.
Shear chains	Resist horizontal forces caused during longitudinal approaches or warping operations.
Uplift chains (not indicated in Figure 8-3)	Prevent vertical shear uplift forces in conjunction with the weight chains. These are often specified for exposed offshore berths with large wave induced vessel movements. This type of chain is however typically used in special cases and is not very common. The use of this type of chain should be verified with the fender supplier. If uplift is expected, this chain can be used on side loaded fenders as well to limit lift movement.
Rope guard chains	Prevent mooring lines from getting caught behind fender panels, particularly on panels with no top tension chains.
Keep chains	Used to moor floating or to prevent loss of fixed fenders in the event of accidents.
Supporting chains	Floating fenders (i.e. foam, pneumatic) and cylindrical fenders require supporting chains, see below Section 8.2.2.

PIANC WG211 Table 8-1: Types of chains

Anchor design and fixing

PIANC WG211 emphasizes that a crucial aspect of anchor design is understanding and identifying the various forces that the anchor will have to withstand, which must be taken into account during the design process. It highlights these forces and also the types of anchors used for fender installation.

Low friction facing design

PIANC WG211 discusses that the design of low friction facings should consider the type and size of fixings, and include a wear allowance. The document includes a friction coefficient table. It also outlines the key factors to be considered in designing low friction facings.

SPECIAL DESIGN CONSIDERATIONS

PIANC WG211 also discusses some of the special design considerations for:

- Parallel motion fender system
- Fender interfaces with mooring lines
- Whole-life consideration
- Corrosion of fender components
- Marine growth
- Design of fender components in icy conditions

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

For many years, Trelleborg has embraced the design principles advocated by the new PIANC WG211, as they represent foundational standards essential for creating durable and well-designed fender panels. With its global approach and local presence, Trelleborg successfully integrates both international and local design standards.

Trelleborg's sales offices and its Design Center in India employ a team of over 60 engineers, each a specialist in their field. This team includes panel engineers, FEA engineers, application engineers, Parallel Motion Fender specialists, and materials specialists, ensuring that we deliver the highest quality designs that meet all project requirements and adhere to both local and international design standards. Our engineers can assist our clients in managing complex design projects and finding the most economical solutions for complicated design scenarios.

Chapter nine

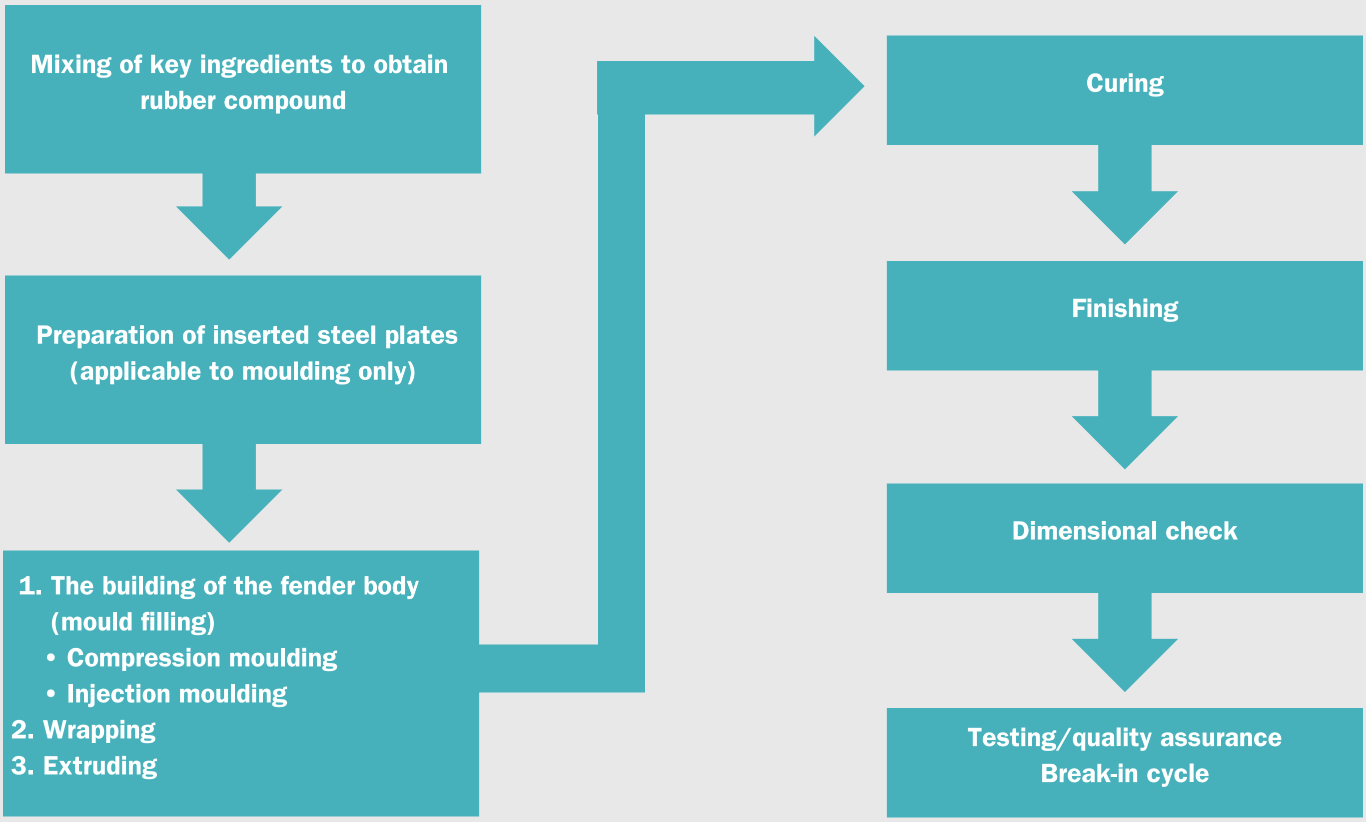
MANUFACTURING OF FENDER SYSTEMS

Fender systems usually consist of several key components: a rubber or foam element for energy absorption, a steel frontal panel for load distribution and hull pressure (if applicable), low friction facing pads to minimize friction and abrasion, and accessories such as chains and anchors. This chapter delves into the general manufacturing process of these components detailing the qualifications required for manufacturers and their workforce, facility standards, requirements for quality control and storage conditions necessary to ensure quality and reliability of the fender systems.

FABRICATION OF RUBBER FENDERS

PIANC WG211 discusses the rubber compounds utilized in fender systems, detailing various materials for rubber compounding. It also provides insights into the materials used, such as natural and synthetic rubber, recycled rubber, fillers, and antioxidants, highlighting their impact on fender performance.

The chapter describes the general process flow of manufacturing rubber fenders, which includes mixing, molding, extrusion, wrapping, and curing, offering valuable information on each stage.



PIANC WG211 Figure 9.1: Manufacturing of rubber fender

FABRICATION OF STEEL PANELS

PIANC WG211 covers the fabrication of steel panels, addressing material selection, design and corrosion protection.

FABRICATION OF UHMW-PE:

The section offers a valuable overview of ultra-high molecular weight polyethylene face pads manufacturing.

FABRICATION OF ACCESSORIES:

This section of PIANC WG211 touches on the fabrication of accessories like chains and anchors, focusing on corrosion protection.

FABRICATION OF PNEUMATIC AND FOAM FENDERS:

It briefly mentions the manufacturing processes for pneumatic and foam fenders, providing a foundational understanding of how these fenders are manufactured.

Overall, the chapter serves as a comprehensive guide for designers and specifiers who document the specification, focusing on manufacturer and workforce qualifications, manufacturing processes, material selection, and quality control.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg's in-house manufacturing facilities meet the industry standards, and we use high-quality materials to ensure our fenders fulfill all project requirements. Our cutting-edge manufacturing facilities are equipped with test presses, allowing us to perform extensive tests on a wide range of fenders. We also conduct independent quality and performance verification on fender system components to ensure optimum performance.

Chapter ten

TEST PROCEDURES OF MARINE FENDERS

This chapter is an important chapter as it outlines recommended testing protocols for evaluating and ensuring the quality of various types of marine fenders. The focus is on standardized testing methodologies that are widely recognized in the industry. These procedures aim to ensure that the engineering data provided in manufacturers' catalogues is accurate and reliable and customers are guided on how they can verify the performance of the fenders that they purchased. By following these common testing methods, manufacturers can offer dependable and comparable data, assisting customers in making informed decisions when selecting marine fenders for specific applications.

PIANC WG211 elaborates on the different types of tests which are classified into:

- Fundamental Testing (catalogue data)
- Type Approval Testing (3rd party verified catalog data) including protocols for VF, TF and AF
- Verification Testing (project specific testing)

FUNDAMENTAL TESTING (CATALOGUE DATA)

Engineers depend on published data for designing fender systems. It falls upon the manufacturer to generate and publish data about fenders and materials, which are derived from fundamental tests. PIANC WG211 lists the minimum fundamental testing that are required for marine fender systems that manufacturers must perform and document.

TYPE APPROVAL TESTING

An independent and qualified third party, as defined in WG211, must observe and/or confirm fundamental testing to acquire a type approval certificate, ensuring the reliability of the data. PIANC WG211 specifies the essential type approval testing data that must be included.

VERIFICATION TESTING

Verification testing for fenders is conducted to ensure that the fenders purchased by consultants, designers, or port owners meet the designed performance specifications for their projects. PIANC WG211 outlines the mandatory tests, highly recommended tests, optional tests required based on the application needs and the physical properties of the materials. These tests are structured to confirm that the fenders will perform as expected in the actual scenario, matching the conditions they were designed for.

MANDATORY TESTS:

- Verification of base performance
- Physical properties of rubber compound

HIGHLY RECOMMENDED TESTS:

- Performance and physical properties testing witnessed by a 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

OPTIONAL TESTS:

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

THIRD-PARTY QUALIFICATION

This section provides guidance on the process of qualifying a third-party for verification testing, ensuring only qualified entities conduct fender testing.

BREAK-IN COMPRESSION

- Uncompressed fenders may exhibit a 30%-40% higher reaction force on the first compression, potentially exceeding the structural limits or pressure tolerances of vessels.
- A "Break-in" compression is compulsory for buckling-type rubber elements in fender systems that have a reaction force exceeding 1000 kN or are for use on load-sensitive structures like dolphins.

THERMAL STABILIZATION BEFORE TESTING

After vulcanization, fenders retain residual heat, which, along with environmental temperature, can affect their performance. Therefore, PIANC WG211 states that it's essential to stabilize their temperature before performance tests. This stabilization is done in a conditioning room set at 23 ± 5°C for a period determined by PIANC WG211 in the below equation 10-1. Prior to testing, fenders should undergo conditioning to ensure accurate results, without the application of correction factors.

PIANC WG211 Equation 10-1

$$t(days) = (12.675\ LN(\Delta T) - 2.0352)\ (maximum\ rubber\ thickness)^2$$

PASS / FAIL CRITERIA

PIANC WG211 states that a fender is considered to perform satisfactorily if it achieves the required base (CV) energy value (Minus the Manufacturing Tolerance) without exceeding the reaction value (Plus the Manufacturing Tolerance) at any deflection up to the maximum designed deflection point. If a fender from a 10% sample of the order fails the test, then a larger sample of 20% is to be tested. Should any fender from this larger sample fail, then the entire batch of fenders (100% of them) must be tested.

DURABILITY TESTING

WG33 and WG211 outline testing criteria for fender durability. WG33 calls for 3,000 cycles of compression to rated deflection in 150 seconds per cycle, while WG211 suggests a minimum of 3,000 cycles to design deflection, and can increase depending on the specific project. PIANC WG211 provides guidance on fender selection and scaled model testing. It introduces combined shear and compression testing. Samples for chemical composition or Thermogravimetric Analysis (TGA) must be taken from the specimen before and after the durability test. The TGA results should match those of the fender body made for the project.

COMPOUND PHYSICAL PROPERTIES TABLE

PIANC WG211 document contains extensive information, including a table detailing the physical properties of the compound including specified properties, testing conditions, and methods. Rubber samples are taken from the production floor and verified through TGA (Thermogravimetric Analysis). For third-party testing, two samples of uncured rubber are provided. Testing also includes tensile properties. While some properties in the testing process are optional, those relevant to high and low temperature applications are incorporated.

TGA TESTING AS A TRACEABILITY TESTING

The chemical composition of fenders can be analyzed using Thermogravimetric Analysis (TGA). PIANC WG211 suggests the following procedure as traceability test:

- A minimum of 10% of the fenders should be selected at random for this testing.
- The TGA values for the cured rubber compound, samples prepared for physical property testing, and actual samples taken from the fender body must match.
- TGA tests should be conducted alongside performance and durability tests to evaluate a fender's quality, with an acceptable variance of ±5% from the established value.

TEST PROTOCOL FOR PEFORMANCE CORRECTION FACTORS

The PIANC WG211 guidelines stipulate the detailed testing protocols for the performance correction factors:

- Velocity factors
- Temperature factors
- Angle factor

Samples of the fenders to be taken for the type approval testing of the performance correction factors for TGA testing. The TGA results should match the results of the commercial fenders.

TESTING OF PNEUMATIC FENDERS

WG33 includes guidelines for the performance testing of pneumatic fenders in Appendix B. WG211 will no longer cover pneumatic fenders and will refer to the requirements of ISO 17357-2014. This change means that designers and testers should directly consult ISO 17357 for the testing of pneumatic fenders, streamlining the process by referring to one primary source.

TESTING OF PNEUMATIC FENDERS

WG211 offers recommendations that include a test protocol for determining performance, alongside material and verification testing. WG211 provides a clear classification of testing requirements for foam fenders. It includes tables for the physical properties of foam, polyurethane (PU), and nylon materials that are used in manufacturing. It also includes velocity factors, angular factors and temperature factors. The document also outlines a procedure for fender pull-through tests and provides calculations for creating scaled-down models that are suitable for testing. Lastly, recommendations for testing of skin thickness and foam density is made using samples extracted from fenders of actual size.

TESTING OF ACCESSORIES:

This section expands its focus beyond rubber and foam testing to include the fabrication of steel accessories such as fender panels. It outlines the test procedure for the air leakage test for fender panels, and it does specify that accessories should undergo Non Destructive Testing (NDT).

UHMWPE PROPERTIES TABLE

The property table for Ultra High Molecular Weight (UHMWPE) materials is clearly defined in PIANC WG211 and includes several characteristics that are important during the design phase or when selecting UHMWPE for fender applications. However, for testing purposes, specific properties are emphasized. These essential properties—such as density, double notch Charpy impact strength, abrasion resistance, and mass melt flow rate—must be rigorously tested to authenticate whether the material in question is truly UHMWPE polyethylene.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg recently added a state-of-the-art marine fender test facility to its Qingdao manufacturing site in China, setting new benchmarks in fender manufacturing in alignment with PIANC WG211 guidelines. The facility is equipped with advanced test presses for comprehensive evaluations of marine fenders under real-world conditions, including shear, fatigue, high-speed, and shear-compression, all within a climate-controlled environment. Trelleborg is the only manufacturer that integrates a test facility within its foam fender factory in Berryville, USA ensuring unparalleled quality control. All Trelleborg fenders are produced in-house at facilities wholly owned by Trelleborg, guaranteeing that every product meets our stringent standards.

Trelleborg supplies all its fenders, adhering to the highest industry standards without exception. Through these rigorous practices, Trelleborg is committed to leading the industry toward reliable and consistent fender performance.

Chapter eleven

INSTALLATION, INSPECTION AND MAINTENANCE

The performance of a fender system over its design life relies on proper installation and maintenance as specified by its fender designers and suppliers. End users, under the guidance of the manufacturers must ensure these guidelines are followed. Given the heavy loads and challenging conditions fender systems operate under, they require regular maintenance. Many facilities often overlook this maintenance. Therefore, it's crucial to consider maintenance needs during the design phase.

Proper installation and maintenance are critical for the fenders systems service life as well as to ensure the safe operations of the port.

HANDLING AND INSTALLATION

PIANC WG211 emphasizes the importance of correct handling and installation of fender systems to avoid any damage that could affect the performance. Suppliers should provide detailed guidelines for handling and installation, allowing installation contractors to prepare appropriate method statements.

SPARES

PIANC WG211 advises on the importance of planning for spare parts for fender systems, focusing on items prone to wear and tear or accidental damage, such as facing pads, their fixings, chains, and chain weak links. It's recommended for end users to collaborate with the fender system designer and supplier to conduct a risk assessment and identify necessary spare parts, which should be included in the purchase order for the complete system.

However, ordering spare rubber fenders is not recommended due to aging concerns. In facilities with many fender systems, like continuous quays, damaged units could be replaced with end units.

STORAGE

PIANC WG211 states that fender manufacturers should provide detailed packing and storage guidelines to prevent changes in properties or surface deterioration of the products. These guidelines, including recommended storage durations, should align with ISO 2230 or a similar standard. PIANC WG211 also highlights the natural hardening process of fender rubber during delayed use, which typically results in temporary hardening.

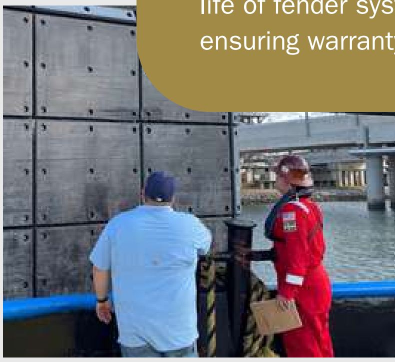
INSPECTION AND MAINTENANCE

PIANC WG211 states that regular inspections are essential for identifying early signs of degradation and detoriations in fender systems, which helps prevent failures and operational disruptions. The ideal frequency and extent of maintenance and inspection (I&M) are hard to standardize due to variations from one site to another, but at a minimum, annual inspections are advised for all fender systems. At minimum inspections should specifically check for any major or minor cracks, signs of over-compression, drooping of the units, panels that are not vertical, as well as any loose or broken chains, and missing fixings or facing pads. Following extreme events like hard berthing, storms, earthquakes, or tsunamis, a thorough inspection of the fender systems is strongly recommended.

Key maintenance areas include inspecting steel panels for coating damage and conducting pressure tests if significant corrosion is present. UHMWPE elements may need replacement or checks for thickness reduction. Chains should be replaced if corroded or reduced in diameter. Fixings and fittings need to be checked for looseness or absence and tightened or replaced as necessary.

Pneumatic fender systems require air pressure checks, replacement of loose or worn rubber sleeves, greasing of swivels, and safety valve inspections. For foam fenders, any cuts or cracks in the skin require immediate repair, and regular removal of marine growth is necessary.

Regular inspections are crucial for extending the service life of fender systems and ensuring warranty validity.



EMERGING TECHNOLOGY

Traditionally, fender system inspections are performed through visual assessments by maintenance crews. However, operators can now leverage emerging technologies that capture real-time and historical data on various parameters such as berthing speed, compression percentage, over-compression, and the number of compressions. This data can be collected and uploaded to the cloud for further analysis. Utilizing this technological advancement can aid operators and end users in enhancing berth utilization, prolonging the lifespan of fender systems, and reducing overall lifecycle costs.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg provides world-class fender inspection services to port and terminal operators worldwide by providing a standardized method for documenting inspections, raising user awareness of fender condition, and enabling managers to review inspection results in real-time for greater insight. The inspections performed by Trelleborg are carried out by trained and qualified experts in accordance with international standards. In this process, a comprehensive assessment report is produced, enabling operators to optimize efficiency, and increase fender durability.

Trelleborg's cutting-edge SmartPort technology allows for the seamless wireless transmission of data generated by our smart fenders. You will receive real-time notifications of any abnormal fender behavior and may instantly access the fender status updates on your smartphone or tablet.

FOR MORE INFORMATION ON OUR FENDER INSPECTION PROCESS DOWNLOAD THE INFOGRAPHIC

Chapter twelve

SUSTAINABILITY OF FENDERS

In 2015, the United Nations established the Sustainable Development Goals (SDGs) to create a more sustainable future, addressing global challenges through 17 goals including those relevant to industry and infrastructure, reducing inequality, and promoting responsible consumption and production. PIANC has placed a strong emphasis on sustainability, acknowledging the climate change challenge in its "Declaration on Climate Change" and advocating for the waterborne industry's sustainable advancement. PIANC's Report EnviCom WG 150 underscores the benefits of adopting a green port philosophy, providing tools and guidance for environmental strategies that support port growth and proactive measures that are ahead of legislation. Many ports now implement sustainability programs, requiring that investments such as fender systems be sustainable, considering the entire lifecycle and recyclability, aligning with the SDGs and national standards.

SUSTAINABLE DEVELOPMENT GOALS

Some of the UN SDG's relevant for fenders include:

9 Industry Innovation and Infrastructure
10 Reduced Inequalities
12 Responsible Consumption and Production
14 Life Below Water

PIANC WG211 serves as an informative guide, highlighting the need for the industry to develop sustainable fendering solutions, including reducing carbon footprint, addressing issues related to rubber sourcing and discusses the fender design, fabrication and material selection. Additionally, it delves into the sustainability of different fender designs, such as pneumatic, cone, and foam fenders, comparing their energy absorption capabilities and overall sustainability.

CARBON FOOTPRINT

PIANC WG211 highlights the importance of assessing the carbon footprint as a major factor in global warming. To address this, it suggests employing Life Cycle Analysis (LCA) and Environment Performance Declarations (EPD).

RUBBER SOURCING

PIANC WG211 states that the production of natural rubber is sometimes associated with unsustainable practices, including irresponsible farming, deforestation, and human rights violations. Efforts are underway to develop sustainable natural rubber fenders. Styrene-butadiene rubber (SBR), being petroleum-based, is not deemed sustainable. Fender products, which extend beyond just rubber, are incorporating more sustainable components, such as recycled carbon black and eco-friendly oils, as part of a broader push for sustainability.

FENDER DESIGN & MATERIALS SELECTION

The document states that end-users, designers, and manufacturers can enhance sustainability in fender systems through thoughtful design and material selection. PIANC WG211 highlights key aspects that need to be considered.

RECYCLING

PIANC WG211 recommends conducting visual inspections and tests for the potential reusing fenders. The recycling efforts should extend to fender components constructed from a variety of materials, including rubber, foam, polyurethane (PU), steel, and ultra-high-molecular-weight polyethylene (UHMW PE). The document also details current practices of fender recycling, as well as, rubber, foam, steel and Ultra-High Molecular Weight Polyethylene (UHMW PE) recycling.

Successful refurbishment of a foam fender, restored to near-new condition: Ideal form of recycling.

RECOMMENDATIONS & CONCLUSIONS FROM PIANC WG211

The global emphasis on sustainability is impacting ports and the manufacturing sector, with challenges like recycling and carbon footprint management, particularly in rubber and fender production. The fender industry, along with end-users, designers, and other stakeholders, are encouraged to lead the way in finding and implementing the most sustainable practices for their projects, including the disposal of fenders. When a project considers the sustainability of fender systems, all involved parties should actively participate to create the most sustainable fender systems possible at present. Despite existing limitations, stakeholders can already take actions to improve the environmental impact and enhance the sustainability of fender systems through intelligent material choices and engineering solutions.

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

GOALS

-50 % CO2 emissions reduction in scope 1 & 2 by 2030

-25 % CO2 emissions reduction in scope 3 by 2030

-25 % recycled or biomass content in all supplies by 2030

ACHEIVED

-40 % CO2 savings (scope 1 and 2) since 2020

At Trelleborg, sustainability is at the core of everything we do. From using sustainable and biodegradable materials in our Fender solutions, to implementing meticulous refurbishment processes in our manufacturing facilities, we take every possible step to reduce our environmental impact while improving port operations efficiency. Our sustainability initiatives are not just an afterthought, but the very foundation on which we build our success.

Chapter thirteen

SPECIFICATION WRITING

PIANC WG211 Chapter 13 serves as a valuable resource for designers and authorities, providing them with point by point guidance on what to be considered in a specification. In short, it is a comprehensive checklist to ensure all necessary aspects are considered and includes a table (refer to the document) indicating where to find the relevant information.

PIANC WG211 outlines that a good specification should cover:

PIANC WG211 states:
"Accurate and complete specifications are important to achieve an economical and durable fender system complying with the required performance."

- Qualifications of Supplier
- Standards and Code of Practice
- Quality Control
- Submittal Requirements
- Project Records Requirements
- Warranty, Product Liability and Compliance
- Vessel, Berthing and Quay Considerations
- Manufacturing, Testing and Quality Requirements
- Delivery, Installation and Storage
- Sustainability

TRELLEBORG'S COMMITMENT TO EXCELLENCE:

Trelleborg is set to launch online tools to facilitate the generation of specifications. The Trelleborg team will also assist with specification development or provide easy-to-copy templates. Committed to meet the specifications outlined in the latest PIANC WG211 document, Trelleborg recommends the involvement of third parties at all critical stages to ensure utmost integrity. Furthermore, Trelleborg recommends conducting fender testing by a third party or use third-party verified equipment instead of mere third-party witnessing, ensuring the highest levels of reliability and performance.

Trelleborg recommends specifying that the rubber fender units should be tested by a 3rd party at a 3rd party press or with a 3rd party verification jig that works independently from the manufacturer's test equipment. A 3rd party witness is not sufficient.

TRELLEBORG

Trelleborg is a world leader in engineered polymer solutions that seal, damp, and protect critical applications in demanding environments. Its innovative solutions accelerate performance for customers in a sustainable way.

Trelleborg Marine and Infrastructure is a leading provider of premium solutions for critical marine, port, and built infrastructure applications. Its innovative polymer and smart technology solutions enhance operational efficiency, safety, and sustainability.

WWW.TRELLEBORG.COM/MARINEANDINFRASTRUCTURE

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