# FLOATING FOAM FILLED MARINE FENDERS

## Technical Specifications

**Rev.1- Oct 2025**

### 1. SCOPE

Floating netless foam filled fenders ***indicative type Trelleborg SeaGuard*** or equivalent, complying to international marine and naval standards and suitable for the side and stern-berthing of Ropax vessels up to LOA 240m and side berthing of Cruise vessels up to LOA 400m.

Intended ship-to-dock operation, safely absorbing the kinetic energy of the approaching vessel with low reaction force and very low hull pressure. Their skin surface will be smooth made of reinforced elastomeric polyurethane, not leaving marks on vessel's hull, colored 'traffic yellow' for high visibility. They will be homogeneously filled with prime quality closed cell polyethylene foam enabling the fender to keep operating even if pierced.

The suspension forces will be taken by a suitable chain fully integrated in the foam core, connecting internally the end suspension fittings at the two ends of the fender. Finally, its end fittings will be integrated with swivel to allow the free rotation of the fender on its longitudinal axis following the vessel's heaving motion versus the quaywall.

Their overall materials, geometry and netless construction of the fenders will ensure high-energy absorption, enhanced durability, low or no-maintenance, long life expectancy, interchangeability and easy relocation / re-deployment to cater to different ships needs.

### 2. PERFORMANCE REQUIREMENTS

Each foam fender shall have the following ***rated base performance*** in compliance to PIANC WG-211, 2024:

**TABLE 1**

| **DIMENSIONS** | | | **ENERGY ABSORPTION** | **REACTION FORCE** | **PRESSURE** |
|---|---|---|---|---|---|
| *Unit Diameter (D)* | *Unit Length (L)* | *Skin Thickness (t)* | *Performance at 60% deflection* | | |
| Ø2200mm | 4000-4500 mm | 21 mm | 643 kN-m | 1089 kN | 155 kPa |

Tolerance: - Dimensions: +/- 4%
- Energy: -10%
- Reaction: +10%
- Skin Thickness: -10%

*The above performance values correspond to constant velocity (CV) of 0.33 to 1.33 mm/sec.*

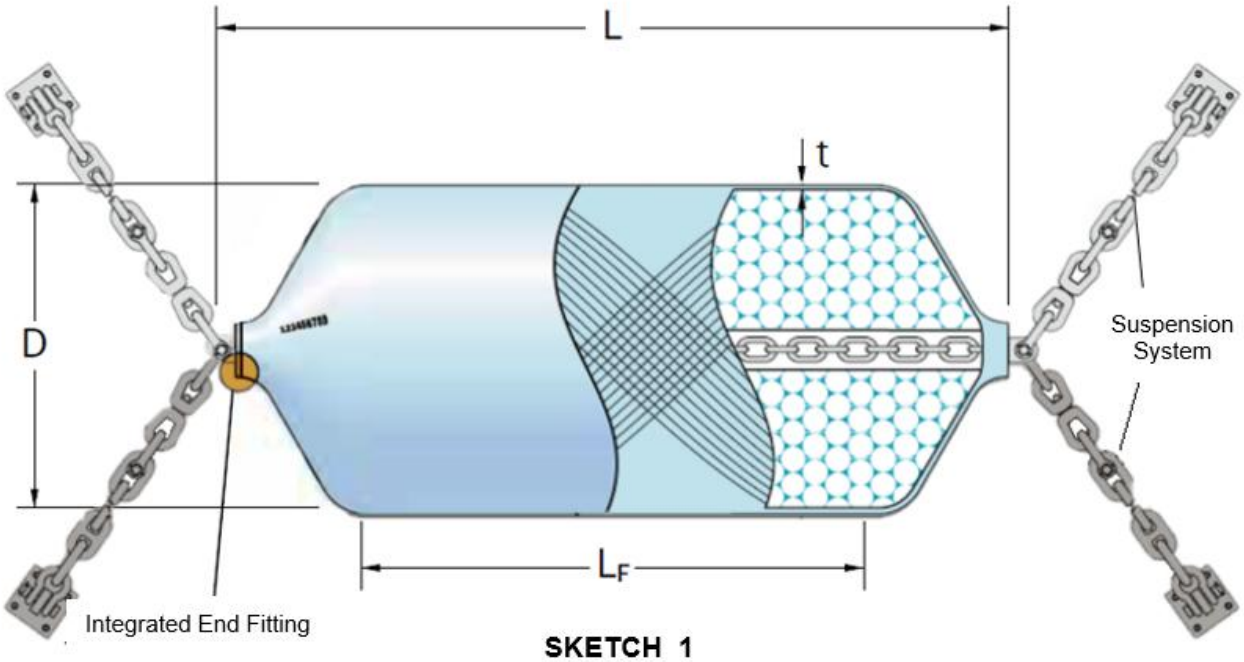
In particular, the foam fenders shall be designed and manufactured so that when they are compressed vertically in their diameter by two flat surfaces extending over the whole length and width of the fender, the fender shall have absorbed at least 90% of the calibrated energy as per the table above (Table 1) when the deflection reaches 60% of its diameter (i.e. the remaining diameter has reached 40% of the initial diameter) without the reaction force to exceed 110% of the above listed.

## FENDER CONFIGURATION

The fender body shall be cylindrical with conical or semi-spherical edges ending at steel suspension fittings in the center at either end of the cylindrical body. The diameter of the median cylindrical body and the length of the fender are given in Table 1. Unit length is measured between ends of the terminal accessories (as per Table 1). The permissible diameter and length tolerance shall be ± 4%.

The suspension terminals at each end shall be connected to each other by a central chain over the longitudinal axis of the fender and shall include a swivel system allowing free fender rotation with respect to its suspension system consisting of chains and shackles. The fender rotation shall be performed vertically on the longitudinal axis of the fender, which means that the swivels shall form an integral part of the terminals rather than the suspension system (which is at an angle to the longitudinal axis of the fender).

The end fittings will be of such size so that they don't come in contact with the compression surfaces (and the ship's hull when the fender is compressed up to 30% of its original diameter (deflection 70%).




**SKETCH 1**

### 3.1. Foam Core

The foam in the fender core absorbs kinetic energy and should maintain its homogeneity under consecutive compressions. It should also remain watertight, even if the external skin is pierced. Therefore, it should be a cross linked closed cell elastomeric PE type foam shaped through a thermo-lamination process. The use of shredded or granulated foam is not permitted and the use of adhesives to bind the layers of foam together is also not acceptable. The foam must have the following properties in accordance with ASTM D-3575:

- Density: 62 kg/m3 Min.
- Tensile Strength: 297 kPa Min.
- Elongation (ultimate): 95% Min.
- Water Absorption: < 0,34 kg/m² (of cut surface)

### 3.2. Skin Elastomeric Material

The fender outer skin should have a thickness ***'t'*** as per above TABLE 1 and consist of polyurethane elastomer reinforced with integrated polyester or nylon filaments. The filament windings should be uniformly distributed and should constitute 75 - 90% of the entire skin thickness. The outer 10% to 25% of the of the elastomeric skin thickness should not contain any reinforcing filaments. The production of the elastomeric skin and the winding of the reinforcing filaments should be a continuous process to ensure their absolute cohesion. The tolerance in skin thickness on the flat length and conical ends can be - 10%.

The elastomer used for the fender skin should be non-marking and solvent free. It should be exclusively the reaction product of toluene diisocyanate, polyether polyol, and an aromatic diamine.

The elastomer should meet following properties (before reinforcement):

| | PROPERTY | TEST METHOD | VALUE |
|---|---|---|---|
| 1 | Hardness | ASTM D2240 | Shore A 75, min. |
| 2 | Tensile Strength | ASTM D412 | 16.5 Mpa, min. |
| 3 | Elongation (at break) | ASTM D412 | 300% min |
| 4 | Tear Strength | ASTM D470 | 32,4 kN/m min. |
| 5 | Flex Life (Ross) | ASTM D1052 | 250.000 cycles, min. |
| 6 | Abrasion Resistance (NBS) | ASTM D1630 | 100 minimum |

**Color**: The color should be Traffic Yellow (RAL1023), throughout the skin thickness.

### 3.3. Reinforcing Filaments

The skin should be reinforced by wrapping continuous filaments applied in a helical pattern, at a helix angle of 45 to 60 degrees in relation to the longitudinal axis of the fender. The wrap should consist of two such filament helixes of equal but opposing wrapping angles. The spacing between the filaments in the same helix should not be more than 3.2 mm, measured in a direction parallel to the longitudinal axis of the fender.

Each wrap shall extend along the entire longitudinal axis of the fender and shall also encase the fender end fittings and secure them to the fender body. Equivalent techniques may be accepted if their equivalence is proven.

The reinforcing filaments should meet following properties:

- Material: Nylon tire cord, weight 2520 denier (0,28 g/m)
- Tensile Strength: 235 N
- Elongation (at break): 18% as per ASTM D412

### 3.4. Reinforced Skin Properties

The reinforced skin after having been produced in accordance to the above or other equivalent method should exhibit the following properties:

3.4.1 *Tensile Strength*: A full-thickness specimen subjected to tensile test (with the direction of pull aligned with the direction of the filament in one of the helixes) it will achieve a breaking strength of 31.0 MPa minimum.

3.4.2 *Elongation* (at break): In the above tensile strength test, the elongation at break of the specimen shall be 16% minimum.

3.4.3 *Tear Strength*: A full-thickness specimen tested in tear, Die C shaped, as in ASTM D-624, and with direction of pull aligned with the filament direction (in one of the helixes) should be found to have a tear strength of no less than 78.8 kN/m.

### 3.5 End Fittings & Suspension System

The fender shall incorporate end fittings at the two ends of its body, connected via a central chain passing through the center of the fender along its central axis. The end fittings shall include double flanges, a circular external and a cone shaped internal terminating to a central tubular member through which the chain will be passing. The configuration of the end fittings will allow the free rotation of the fender.

The elastomeric skin shall integrally encase the foam core, the central tubular member and the inner conical flanges of the suspension end fittings. The reinforcing filaments of the skin shall be also fully wrapped around the annular seat of each end fitting.

The end fittings at the ends of the fender shall connect to the central chain passing through the center of the fender and the tubular central members so that tensile loads are transferred from the mooring chains to the attachment elements through the central chain. The connection between the end fittings and the central chain shall allow for tensioning or adjustment of the tension in the central chain.

All the metal parts of the fender shall be of hot-dip galvanized steel, as per ASTM A-123 or equivalent. The end fittings and the internal chain and all parts in between shall be designed and dimensioned to transmit the fender safe working load, as shown in Table 2 below.

### 3.6 Suspension System

The suspension system of each fender shall include four (4) chain lines, such as the indicative drawing of the Appendix, i.e. two (2) suspension chains above and two (2) mooring chains holding the fender below. The latter will be considered optional, subject to the detailed application design on each fender location.

Each chain cable will consist of the following components:

3.6.1 Chains & Shackles

Made of hot-dip galvanized steel, grade 2, according to ASTM A-123, or equivalent, with a minimum zinc coating thickness of 85 microns (μm). The minimum breaking load of each chain line shall be according to Table 2. Each chain line shall include a 'weak link' in the form of a shackle with a strength approx 25% less than the strength of the rest of the line, so that in case of accident the pier infrastructure is protected.

3.6.2 Chain Brackets

The two upper suspension chains will be attached to steel brackets type CB2-S or equal, made of grade SB35 / S275, hot-dip galvanized in accordance to ASTM A-123 and with a min. zinc coating thickness of 100 microns (μm).

3.6.3 Sheaves on Guide Rails

The two lower chains lines shall wrap around pulley sheaves, so that they are secured at the upper part of the structure, to be easily accessible in case of maintenance or fenders relocation. To cope with tidal variation, the pulley sheaves will be sliding on a guide rail fixed at the face of the quaywall. The guide rail shall be of stainless steel AISI316 and fitted with low friction lining.

3.6.4 Resin Anchors

Resin anchors shall be of EC2 type or equivalent, for existing concrete, made of galvanized steel, grade 8.8, in accordance with ISO 898 or equivalent. Their dimensions shall ensure a strength of at least 50% greater than the weak link in the chain. The epoxy resin shall be type Hilti RE-500 or equivalent.

**TABLE 2 - Suspension System Dimensions & Strength**

| Property | Fender Size Φ2200 |
|---|---|
| Safe End-Pull Load: | SWL 151 kN |
| Suspension Chains & Shackles<br>Diameter:<br>Min. Breaking Load: | <br>Φ32mm<br>MBL 583kN |
| End Fittings & Internal Central Chain:<br>Min. Breaking Load: | MBL 370 kN |
| (*) *The length of each chain line is determined by the quay height and stated in the tender material supply list.* | |

## 4. QUALITY CONTROL

### 4.1. Manufacturer Qualifications

The manufacturer shall have the following certificates which will be submitted by the bidders upon submission of their bids:

4.1.1 Fender Drawing and Manufacturer's Technical Brochure with specs of the offered foam fenders.
4.1.2 Type Approval from a Classification Society IACS member for the offered foam fender type.
4.1.3 Quality Management System Certificate ISO 9001 (including foam fenders).
4.1.4 Environmental Management System Certificate ISO 14001.
4.1.5 Manufacturer's Liability Insurance Certificate issued by a recognized international Insurance Organization for insurance amounting to not less than € 2.5 million per incident.
4.1.6 Copy of Test Certificate from a previous supply of same type of fenders.
4.1.7 Reference List of at least 15 completed projects of which at least 2 will concern naval applications. References of fenders that have not completed 5 years since installation will not be taken into account.
4.1.8 Draft of 5-year Manufacturer's Warranty.

**Note**: ***Lack of even one of above will constitute reason for rejection.***

### 4.2. Product Quality Control Certificates

Following Quality Control Certificates shall be submitted upon delivery of the goods:

4.2.1 Manufacturer's Certificate of Conformity stating compliance with the present specifications.
4.2.2 Control Certificate by an International Classification Society, IACS member, endorsed by the Hellenic Republic which will certify following test controls the fenders under supply:
- 4.2.2.1. Compression / Performance Test
- 4.2.2.2. Fatigue Test
- 4.2.2.3. Pull-through Test
- 4.2.2.4. Reinforced Skin Test (for the properties of par.3.4 above)
- 4.2.2.5. Physical and mechanical properties of the fender materials
- 4.2.2.6. Dimensional measurements of the fenders.

The Classification Society will attest that the tests were carried out in the presence of (*witnessed by*) its appointed inspector/s and with duly calibrated testing equipment.

The Compression Performance Test (4.2.2.1), in particular, shall be performed at an independent suitably equipped laboratory certified for carrying out such tests. Alternatively, they can be carried out at the manufacturer's own test facilities, *but only if the test measurements are done by a 3rd party certified & calibrated portable measuring device.*

The cost of performing all tests shall be borne by the Contractor.

### 4.3 Test Sampling

For the control and test procedures, following samples shall be taken at random:

4.3.1 Compression Test: 10% of the order lot (but no less than one fender from each size).
4.3.2 Fatigue Test: at least one (1) fender.
4.3.3 Pull-through Test: at least one (1) fender.
4.3.4 Reinforced Skin Test: 10% of the order lot.
4.3.5 Material Test: 100% of the production lot.
4.3.6 Dimensional Measurements and Skin Thickness: 100% of the ordered fenders.

### 4.4 Test Procedures:

The specimen from above random sampling will be subjected to the following tests:

#### 4.4.1. ***Compression – Performance Test of the fender:***

Shall be performed on a random sample of 10% of the production lot. The fender/s shall be compressed perpendicular to their diameter between two parallel flat surfaces until the spacing between the surfaces reaches 40% of the initial fender diameter (60% deflection). The test load shall be recorded in maximum increments of 25 mm (or 1") out of which the curve of reaction force to deflection will occur.
The integral of the reaction force curve will depict the energy absorption curve.

*The resulting energy absorption and the reaction force, as measured above, must meet the 'PERFORMANCE REQUIREMENTS' in par.2 above of the present specification.*

***Recovery**: After the fender is compressed up to 40% of its initial diameter, the fender should recover 90% of its initial diameter no later than two (2) minutes from zero load, and 95% of its initial diameter no later than 30 minutes after zero load.*

*Laboratory Equipment & Procedure*

4.4.1.1. The test is conducted on a random sample 10% of the fender lot, and in any case not less than one fender from each size.

4.4.1.2. The test apparatus must be equipped with a calibrated load cell, or a pressure transducer and linear transducer.

4.4.1.3. The test apparatus shall be capable of recording and storing load cell data or transducer data at increments of 0.01H-0.05H, where 'H' is the nominal height / diameter of the fender. The details of sample and calibration shall be recorded.

4.4.1.4. Before performing the compression / performance test, the fender temperature shall be stabilized at 23° ±5° C *for at least 24 hours.*

4.4.1.5. The compression speed will be constant velocity at 0.33 to 1.33 mm/s. Adjustments using velocity correction factors are not allowed.

4.4.1.6. Compression angle shall be 0° (vertical compression).

4.4.1.7. 1st compression cycle (without measurement): The measurement test shall be preceded by break-in compression on the fender under test until its rated deflection.

4.4.1.8. The load is removed, and the fender is let to recover for up to one hour. Measure the recovery values stated in 4.4.1 after 2 minutes and 30 minutes.

4.4.1.9. 2nd compression cycle (measured): The fender compression is repeated to its rated deflection and the resulting performance values are recorded.

4.4.1.10. The recorded data are evaluated and the curves of performance, energy and reaction force to deflection are depicted.

4.4.1.11. Test report shall be provided.

**Accept / Reject:** The fender under test, compressed to its rated deflection of 60%, should absorb the specified energy with a maximum permissible deviation of -10% by assigning the specified reaction force with a maximum permissible deviation of +10%. If a fender fails the performance test, an additional 10% random sample of the production lot shall be tested. Rejected fenders shall be replaced by new fenders which shall be retested.

### 4.4.2. ***Fatigue Test of the fender***

One fender from the production lot shall be taken at random. The fender shall be pressed perpendicular to its diameter between two parallel flat surfaces until the distance between the surfaces reaches 40% of the initial fender diameter (60% deflection). Release the load and repress as before for 10 complete cycles of loads and releases. The fender may be rotated 90 degrees after 5 compression cycles. Both loading and releasing shall last one (1) minute each. A period of five (5) minutes must lapse between each cycle

**Accept / Reject:** Permanent deformation, cracks or tear of the fender skin, or detachment of the end fittings constitute failure of the fender in this test. In such case the test is repeated with twice the sample (two fenders) and if in the second test even one of the fenders fails, the whole lot is rejected.

### 4.4.3. ***Pull-through Test of the fender***

One fender from the production lot shall be taken at random. At an appropriate arrangement, a pull load is applied, in the direction of the longitudinal axis of the fender, equal to the safe working load of par. 3.5, so to control the pull-through strength of the end fittings and the central chain.

**Accept / Reject:** Failure of the terminal accessories, the internal chain, or the skin constitutes a failure of this test. After loading, signs of permanent damage, such as cracks or tears of the fender or terminal accessories, shall also constitute failure of this test. In such case the test is repeated with twice the sample (two fenders) and if in the second test even one of the fenders fails, the whole lot is rejected.

### 4.4.4. ***Reinforced Skin Test***

The control is carried out on a random sample 10% of the fender lot, and in any case not less than one fender from each size. Each test consists of taking 2 cores out of the fender skin, one from the cylindrical body of the fender, and one from its conical/hemisphere section. The cores shall have a diameter

of 6 mm (minimum) to 12 mm (maximum). The thickness of the elastomeric skin and the arrangement of its reinforcements is examined in relation to the requirements of above paragraphs 3.2. thru to 3.4.

**Accept / Reject:**

Where the skin thickness measurement is less than the specified thickness by more than 10 percent, reject the fender. If the tested fender is rejected the Manufacturer shall then conduct thickness tests for an additional 10% of the production lot fenders. Replace rejected fenders with fenders meeting the provisions of this specification. Test replacement fenders for skin thickness as specified herein. Tests shall be witnessed by a certified, independent inspection agency such as ABS, if required in the contract documents. The manufacturer shall provide notification at least 10 working days prior to conducting skin thickness tests.

After the skin thickness control is terminated, the holes from where the core samples had been extracted are filled with elastomer of same composition and thickness as the skin. No supplement of nylon reinforcements is required. The integrity and functionality of the fender are not affected by this sampling.

### 4.5. Dimensional Measurements and Visual Inspection

100% of the fenders under delivery will be checked as concerns dimensions and are visually inspected for uniformity and surface smoothness as well as absence of defects.

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## 5. INSTALLATION WORKS

5.1. Removal of existing old fenders and complete trimming of any old steel anchors, plating and other protruding objects to avoid damage to the new fenders.

5.2. Restoration of the quaywall face resulting to a smooth uniform surface with coefficient of friction ≤ 0.20 in dry conditions, ensuring uninhibited fender rolling and protection from wear.

5.3. Installation of the fixings of paragraph 3.6. and suspension of the herewith specified fenders.

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## 6. HANDLING, OPERATION & MAINTENANCE MANUAL

The materials shall be accompanied by their manufacturer's manual in Greek and/or English language, with instructions for handling, installation of fenders and suspension parts, operation, maintenance (if required) as well as repair in case of accident. A repair kit marked with expiry date shall be provided. The maintenance materials, if in liquid form, should not be harmful to the environment.

## 7. MANUFACTURER'S WARRANTY

The fenders shall be accompanied by a five-year (5-year) warranty of good operation by the **manufacturer** of the fenders (not by the supplier). The bidder will submit draft of warrantee in English language, whereas the original will be delivered with the goods.

## 8. REFERENCES – BIBLIOGRAPHY

The following publications are supplement to this specification and are provided as reference where more details are required.

8.1.1. U.S. Department of Defense (DOD): RR-C-271 – (1995) Chains and Attachments, Welded and Weldless.
8.1.2. Federal Standards (FED-STD): PPP-C-1752B – (1990) Polyethylene Plastic Foam.
8.1.3. ASTM International (ASTM):
8.1.3.1. A123 – Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
8.1.3.2. A153/A153M – Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Hardware.
8.1.3.3. D412 – Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension.
8.1.3.4. A413/A413M – Carbon Steel Chains.
8.1.3.5. D624 – Rubber Property Tear Resistance.
8.1.3.6. D885 - Test Method for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manmade Organic Base Fibers.
8.1.3.7. D1052 – Measuring Rubber Deterioration-Cut Growth Using Ross Flexing Apparatus.
8.1.3.8. D1630 – Rubber Property – Abrasion Resistance (NBS Abrader).
8.1.3.9. D2240 – Rubber Property – Durometer Hardness.
8.1.3.10. D3575 – Flexible Cellular Materials Made from Olefin Polymers.
8.1.3.11. F2192-02 – Test Method for Determining and Reporting the Berthing Energy and Reaction of Marine Fenders.
8.1.4. American Welding Society (AWS): D1.1 – Structural Welding Code – Steel.
8.1.5. PIANC – International Navigation Association: Report of WG33 – Guidelines for the Design of Fender Systems.

# APPENDIX

## Indicative GA Drawing

## Existing Site Photos