Ref. No. MF-410 (A)

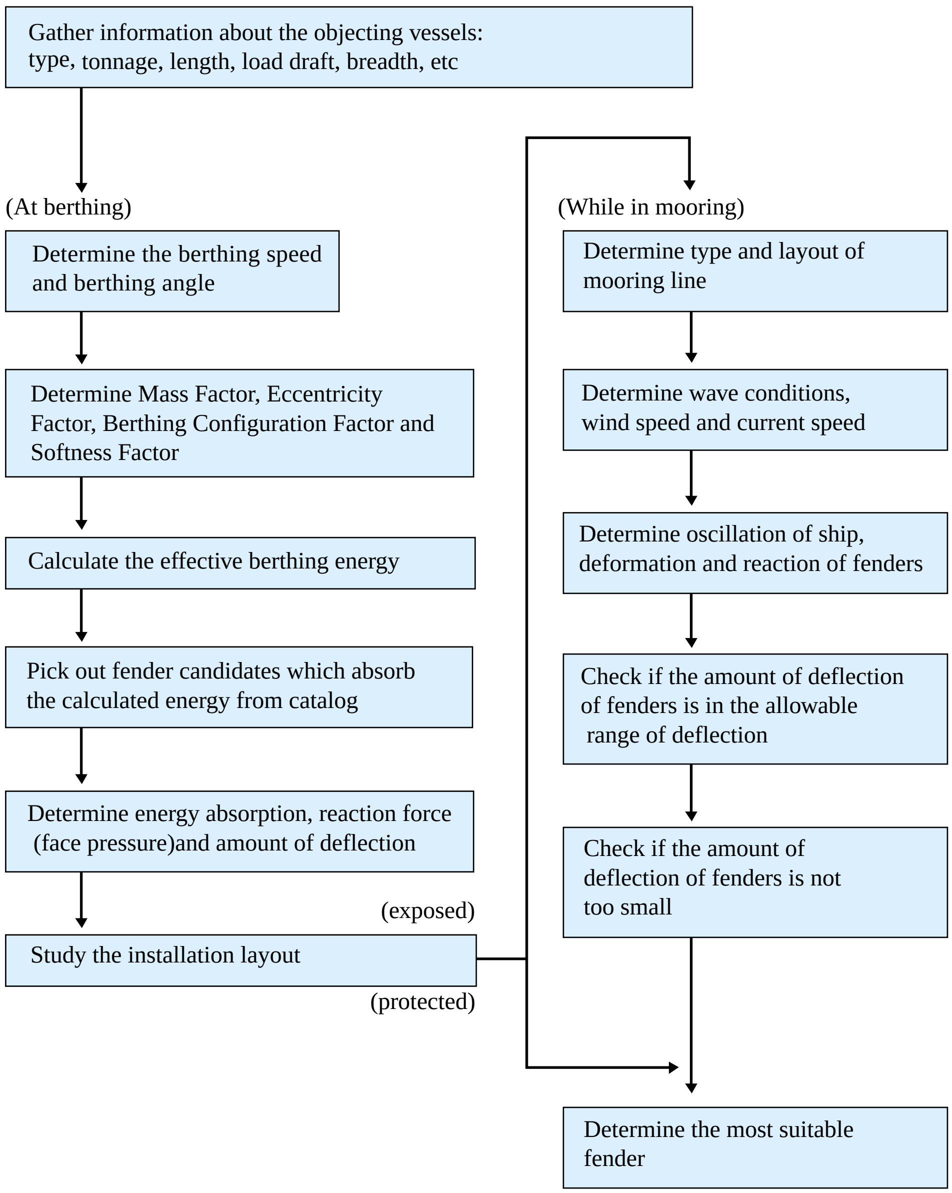
SUMITOMO

# NEW SELECTION OF FENDER

The New Answer for Approaching Right Fenders

# 1. Flow Chart of Designing Fender

Fender systems for marine structures are generally designed according to the following procedure:



## 2. Design Standard

Following Standards and report are widely taken as design standard.

- Technical Standards for port and harbour facilities in Japan
- British Standard BS6349
- EAU(German Standard)
- Various informations about fender design are given by PIANC Report (Report of the International Commission For Improving the Design of Fender Systems)

## 3. Berthing Energy

Berthing energy is calculated by the following kinetic equation

$$Ef = \frac{Wa}{2g} V^2 \cdot Cm \cdot Ce \cdot Cc \cdot Cs \qquad (4.1)$$

Where Ef: Berthing energy (tf·m)

g: Acceleration gravity (9 8m/sec$^2$)

Wa: Water displacement of the berthing ship (tf)

V: Berthing Speed of the Ship at the movement of impact against the fender (m/sec)

Cm: Virtual mass factor

(As a vessel makes contact with the berth and its movement is suddenly stopped by the fenders, the mass of water moving with the vessel adds to the energy possessed by the vessel This is called "Mass Factor" and the weight of the water is generally called "Additional Weight")

Ce: Eccentricity factor

(In the case when a vessel contacts a berth at a point near its bow or stern, the reaction force with give a rotational movement, which will dissipate a part of the vessel's energy)

$$Ce = K^2 / (A^2 + K^2) \qquad (4.2)$$

Where K: Radius of rotation of the vessel (usually 1/4 of vessel's length)

A: Distance of the line paralleled to wharf measured from the vessel's center of gravity to the point of contact.(usually 1/4- 1/5 of vessel's length)

Cc: Berth configuration factor

This is the portion of berthing energy which is absorbed by the cushion effect of water between the approaching vessel and the quay wall

Cs: Softness factor

This is the portion of berthing energy which is absorbed by the deformation of the vessel's hull and fender

## 4.Speed Correction Factor

Relating the elasticity of rubber, the following circumstances could affect the reaction force and energy absorption capacity of the fender.

[a] Aging(Harder)
[b] Compression speed effect(Harder)
[c] Temperature(Softer to Harder)
[d] Repetitive compression(Softer)

It is general that the amount of each effect is not clear, and these effects are considered to be unity in total.
On the other hand, the each amount of effect is different and the effect by compression speed can be principal.
As far as the design is made based on Japanese Standard, we had better consider some safety in energy absorption capacity by speed effect. But as safety factor is considered independently or in other condition in British Standard or German Standard, we could pick up the speed factor and make the effect clear.
There is a manufacturer who applies the wrong speed factor without note in the description of performance in the catalog. Here we would like to explain what are important in the consideration of speed effect which will be called "speed factor."

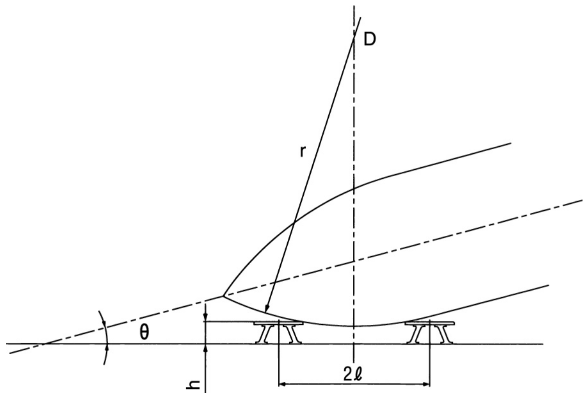
[1] Speed factor isn't constant by absolute compression speed(mm/sec)but relative compression speed(%/sec)in fender deformation.

[2] Compression speed changes from berthing speed to nil in berthing process.
When we consider this factor in design, we should take the fact into consideration.
As a conclusion, the speed effect is different from the height of the fender(the distance from quay surface to the top of buffer)and we should calculate the effect with the consideration of berthing process. (At the end of berthing process, the speed becomes nil).
Please contact us for further information if you have interest.

# 5. Fender Installation

5-1. Installation pitch

Minimum installation pitch of fender can be calculated by the following equation




$$2\ell \leqq 2\sqrt{r^2-(r-h)^2} \qquad (9.1)$$

Where $2\ell$: Installation pitches of fenders (m)

r: Bent radius of board side of ships (m)

h: Height of the fender when effective kinetic energy of vessels is absorbed (m)

As the bent radius is usually not known,
we can estimate the radius by ship's length (L) and ship's width (B).

$$2\ell \leqq 2\sqrt{h\left(\frac{B}{2}+\frac{L^2}{8B}-h\right)} \qquad (9.2)$$

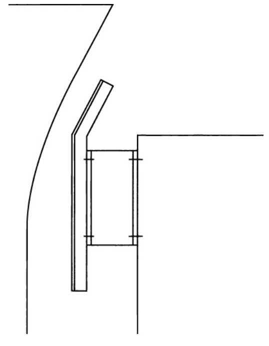
Module of berthing structure provides the final pitch of fender installation.

5-2. British Standard

Some examples are shown as recommendation of fender layout.
For continuous quay the installation pitch is recommended to be less than 15 percent of the ship.

5-3. Flare angle

The ships like car carrier and container vessel have sometimes big flare angle in the hull.
In that case we should consider the contact angle vertically and fender system itself..



# 6. Berthing with Angle

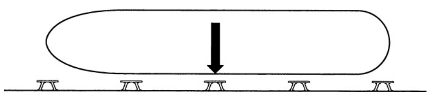
The ship usually approaches with some angle, like 15 degree, to the quay and then moves to the berth parallely.

We describe how we consider the berthing with angle in the fender design.

6-1. Continuous quay

[a] Parallel berthing

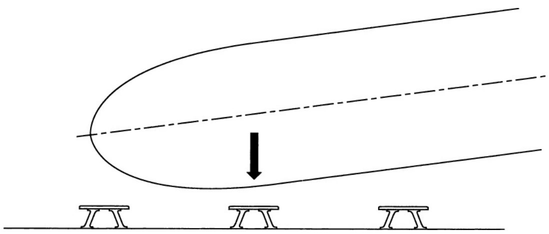
Ship contacts the plural fenders.



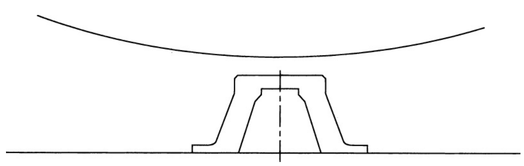
Fenders have enough capacity to absorb berthing energy.

[b] Berthing with angle

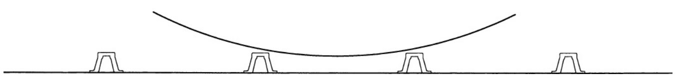
b-1 Contact to one fender



When the ship berths with some angle and contacts to one fender, the curved part of the hull contacts the fender. In that case we can consider that the fender is compressed parallelly. (We need not consider the angular compression).



b-2 Contact to two fenders

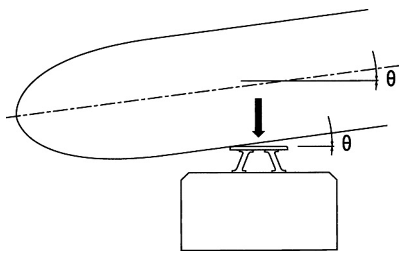


Though the fender is compressed with angle, the berthing energy can be absorbed because the ship contacts to two fenders.

6-2. Dolphin

Distance of two main dolphins is generally designed to let the fenders touch the straight part of the hull.

It means that if the ship berths with an angle, the fender is compressed with the angle.




Six degree has been widely used in fender design in Japan and ten degree is often recommended to consider in USA.

## 7. Hull Pressure

When we design the berthing facility for the tanker or bulk carrier, we should consider the impact force on the ship's hull; (the maximum reaction force divided by the area of contact between fender front and ship).

In the PIANC report 1984, the average figure from 200 terminals for large vessels are shown.

Oil Tanker: 21.4 tf/$m^2$

Bulk Carrier: 21.7 tf/$m^2$

Container: 30.8 tf/$m^2$

LNG: 19 tf/$m^2$

## 8. Necessity of Steel Frame

[1] Hull pressure

The hull pressure of ordinary trapezoidal fender is about 100 tf/$m^2$, and the lowest hull pressure of direct contact fender is 50 tf/$m^2$ by Beta type fender.

If we need the lower figure, we should combine the rubber buffer and the steel frame

[2] Ship's belt

Some kinds of ships like ferry ship or fishery boat have ship's belt, which sometimes damages the fender.

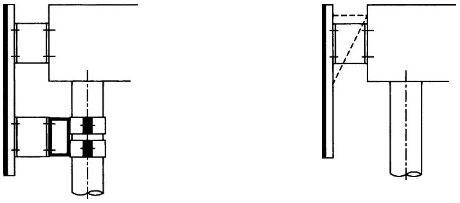
It is usual to install the fender with the steel panel.

In this case, plastic pad is not necessary or recommendable because the ship's belt easily slips on the steel surface. (T30 type is suitable for any kind of fishery boat. Steel frame is not necessary)

For the tanker, LNG and LPG carrier, we should avoid the spark by the contact between steel and steel

[3] Long coverage with shorter rubber buffer.

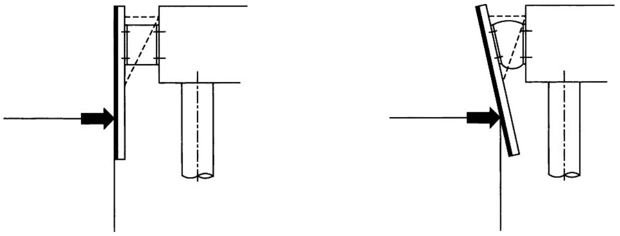
When the covering area is much longer than the fender installation area, a steel frame is necessary.



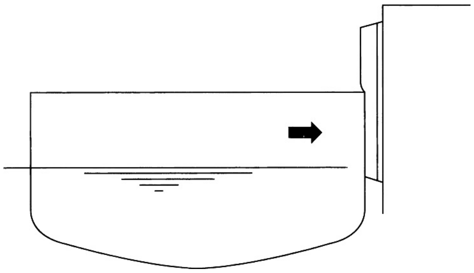
[4] It is recommendable to have the frame length to cover from HWL to 0.5m lower below deck level of a minimum vessel at LWL.

[5] In case when the steel frame sticks out in comparison with the buffer position, the fender performance at the end-loading compression should be studied.

Please contact us to study the performance data.



[6] In case when the fender is long (exceeding 2m), the fender size shall be determined in consideration with its partial compression.



## 9. Friction Force

Besides the kinetic energy of the vessel, friction loads caused by shift-movement, the rolling or pitching of the vessel shall not be overlooked.

These load may sometimes damage the fender system seriously whose designers paid little attention to these loads.

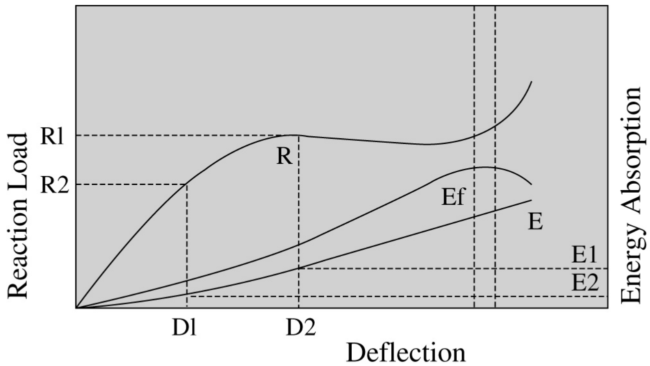
These loads result from the friction between the vessel's hull and the rubbing panel of the fender system on the fender unit itself.

The following table shows the friction coefficient between the smooth contact ship's surface and the fender surface shown in the British Standard (BS6349).

| Material | Friction coefficient (dry condition) |
|---|---|
| Rubber | 0.5 |
| Timber | 0.3 |
| Nylon | 0.2 |
| Polyethylene | 0.2 |

## 10. Deflection of Fender

We should clarify the rated deflection and maximum deflection until which we can compress the fender.
The typical performance curves of buckling type fender is as below.




Here we introduce the efficiency factor (Ef).

$$Ef = E/R \qquad (14\text{-}1)$$

At each deflection (D1) we can calculate the efficiency factor.
We call the deflection at which Ef is the maximum as "rated deflection".
We call the deflection until which the fender is not broken as "max. deflection"
Ef is taken for fender design

## 11. Study of the wave and wind force while in mooring

When the mooring facility locates in the exposed place to the ocean and can get the incursion of the long-period waves, the kinetic energy due to the oscillation of a moored ship may exceed the berthing energy.
In that case it is suggested to study the extend force due to the oscillation of the moored ship by computing the wave force, wind pressure, current pressure, in the considerations of fender characteristic curve and elongation curve of mooring rope, in Japanese Standard.
In British Standard, several discussions about the method to study the ship's movement during mooring are made.
They describe that there are three methods, miniature method, analytical method and computational model method.
But definite rule or method are not shown.
In this situation, we, Sumitomo Rubber, analyze the design condition and study by computer simulation.
If you have the same situation, please consult with us.

## 12. Performance Test

[1] Compression test should be carried out on the actual fender and the performance (absorbed energy and maximum reaction) of the fender should be confirmed.

[2] The test result should be compared with the figures in the specification. Correction factor shouldn't be applied to the test result if that is not described in the specification.

[3] The performance of fender is expressed by value of energy absorbed during the compression of fender up to the prescribed deflection and the maximum value of reaction load thus generated.
The prescribed deflection is the deflection at which the ratio (E/R) of the value of energy absorption (E) to the value of reaction load (R) derived from the standard performance curve for fender, makes maximum.

[4] In the performance test of fender, vertical compression test is used in general. Angular compression test is to be carried out if necessary. The compression process at the speed 2~8cm per minute is to be repeated for three times up to the prescribed deflection. The average data obtained in the second and third tests shall be the performance values. The average value shall be more than the prescribed performance value for the energy absorption and than the prescribed performance value for the maximum reaction load.

[5] The specimen for testing shall be one piece per ten pieces.

[6] The compression machine for test should be inspected periodically and certified by the inspection organization.

[7] The compression machine should be equipped with the scale which shows the actual value of reaction

[8]If any specimen for test does not satisfy the specifications, retest shall be conducted on one piece per five pieces of the remainder, excluding the rejected specimens If this results in further rejects, tests shall be conducted on the all remainders.

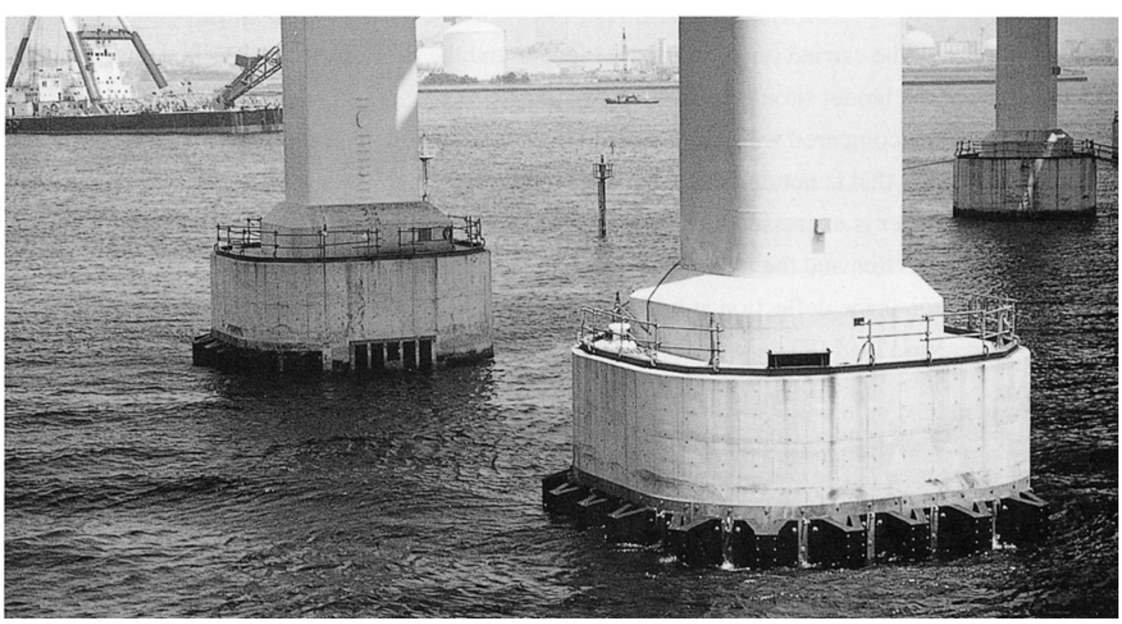
## 13. Dimension Tolerance

[1] The tolerances in the dimensions of fender shall be as follows.

| | Length | Width | Height | Thickness | |
|---|---|---|---|---|---|
| | | | | Standard | Exception |
| Tolerance | +4%<br>-2% | +4%<br>-2% | +4%<br>-2% | +8%<br>-2% | +10 %<br>-5% |

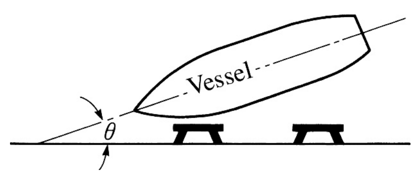
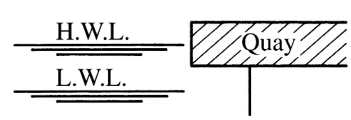
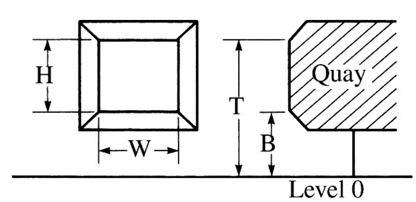
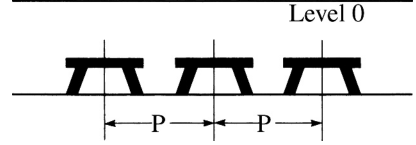
[2] If bolts are used far fixing fender, tolerances far bolt hole on fender shall be as follows.

| | Diameter of hole for bolt | Pitch of holes Tolerance |
|---|---|---|
| Tolerance | ±2mm | ±4mm |



# Required Information for Designing Fender System

The following tables indicate the basic technical information required for the design of a fender system. Although it is possible to propose a provisional system for budgetary purposes based on more limited information, the information as detailed as required below would enable us to propose the most suitable fender system for your berth :

| Item | | Information | | Remarks |
|---|---|---|---|---|
| **GENERAL** | Project<br>Port<br>Country<br>Contractor<br>Consultant | | | |
| **VESSELS** | Kind | Cargo Vessel, Tanker, Ore Carrier,<br>Ro/Ro Vessel, Container, Ferry | | |
| | Weight | Min. | Max. | |
| | Gross Tonnage<br>Deadweight T<br>Displacement T | | GT<br>DWT<br>DT | at least one of the three |
| | Length<br>Width<br>Depth<br>Load Draft<br>Hull Pressure | | m<br>m<br>m<br>m<br>ton/m² | |
| **BERTHING CONDITIONS** | Berthing Speed<br>Angle ( θ )<br>Method | 1/4 point or | m/sec<br>degree |  |
| **EFFECTIVE BERTHING ENERGY** | | | ton-m | Your requirement |
| **BERTH** | Type | Solid (Gravity, Sheet-pile, Cell type, etc)<br>Flexible (Pier, Dolphin, etc)<br>or ( ) | | Drawing of the berth would be appreciated. |
| | Length<br>Depth of Water<br>Tide<br>H.W.L.<br>L.W.L. | | m<br>m<br><br>m<br>m | To decide type, size and length of the rubbing panel of the fender or fender itself<br> |
| | Fender Fixing Area<br>Height ( H )<br>Width ( W )<br>Vertical Location<br>Top ( T )<br>Bottom ( B )<br>Fender Installation<br>Pitch/Spacing ( P )<br><br>Allowable Reaction Force | | <br>m<br>m<br><br>m<br>m<br><br>m<br><br>ton | To decide the type and size of the fender<br><br> |