APPENDIX A

DESIGN OF FENDERS

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A.1 Example 1

Given

Details of design vessels for a proposed solid pier are given as follows :

	Type 1 Vessel	Type 2 Vessel
Length	8.0 m	35.0 m
Beam	5.0 m	20.0 m
Depth	1.2 m	2.5 m
Draft	0.7 m	1.5 m
Displacement	25 tonnes	400 tonnes
Bent radius of bow side of vessel	10.0 m	25.0 m

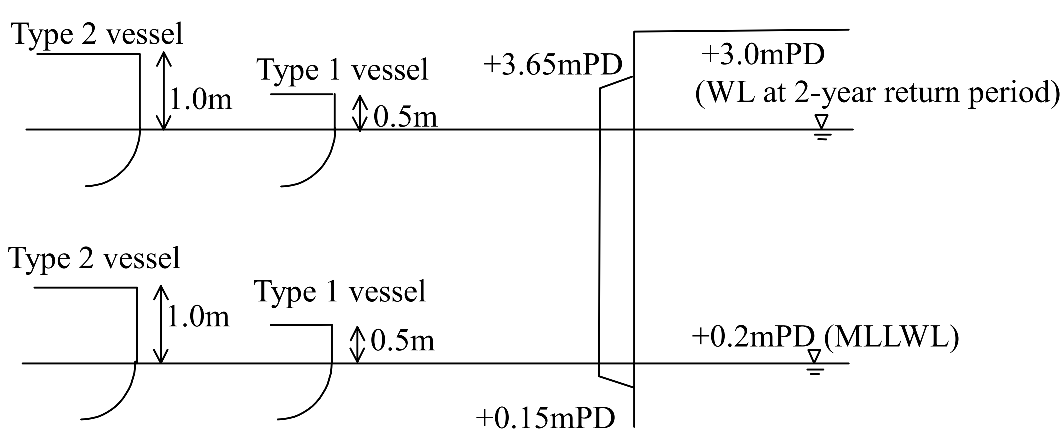
Determine the layout and the size of rubber fenders.

Solution

(a) Length of fenders

Low water level = +0.2 mPD
High water level = +3.0 mPD
Freeboard for Type 1 Vessel = 1.2 – 0.7 = 0.5 m
Freeboard for Type 2 Vessel = 2.5 – 1.5 = 1.0 m
Length of fenders = 3.5 m, extending from +0.15 mPD to +3.65 mPD to allow berthing under low and high water levels.

The relationship between fenders and vessels at different water levels is shown as follows :



(b) Spacing of fenders (See Figure 8)

The length of the small vessel (Type 1 Vessel) using the pier = 8.0 m
Maximum fender spacing = 0.15 x 8.0 m = 1.2 m

Smallest bent radius of bow side of vessel = 10.0 m
Height of fenders = 0.25 m
Maximum fender spacing = $2 \times [10^2 - (10 - 0.25)^2]^{1/2} = 4.4$ m

Therefore, use fender spacing of 1.2 m.

(c) Size of fenders

Based on the dimensions of the vessels :

- Distance of the point of contact of Type 1 Vessel from its centre of mass = 3.0m
- Distance of the point of contact of Type 2 Vessel from its centre of mass = 12.0m

Assume that the angle between the line joining the point of contact to the centre of mass and the velocity vector of the vessel = 45°

Calculation of berthing energy (see Section 5.12 of Part 1 of the Manual) :

	Type 1 Vessel	Type 2 Vessel
V_b	0.4 m/s	0.3 m/s
$C_m = 1+2(D_v/B_v)$	1+2(0.7/5.0) = 1.28	1+2(1.5/20.0) = 1.15
$C_e = (K_v^2+R_v^2\cos^2\nu)/(K_v^2+R_v^2)$ Where $K_v = (0.19C_b + 0.11) L_v$	$K_v = [0.19\times25\times10^3 / (8 \times5\times0.7\times1025) +0.11]\times8 = 2.2$ $C_e = (2.2^2+3.0^2\cos^2 45) /(2.2^2+3.0^2) = 0.67$	$K_v = [0.19\times400\times10^3 / (35 \times20\times1.5\times1025) +0.11]\times35 = 6.32$ $C_e = (6.32^2+12.0^2\cos^2 45) /(6.32^2+12.0^2) = 0.61$
C_s	1.0	1.0
C_c (for solid pier)	0.9	0.9
Berthing energy	$0.5(1.28\times25\times0.4^2\times0.67\times 1.0\times0.9) = 1.5$ kNm	$0.5(1.15\times400\times0.3^2\times0.61\times 1.0\times0.9) = 11.4$ kNm

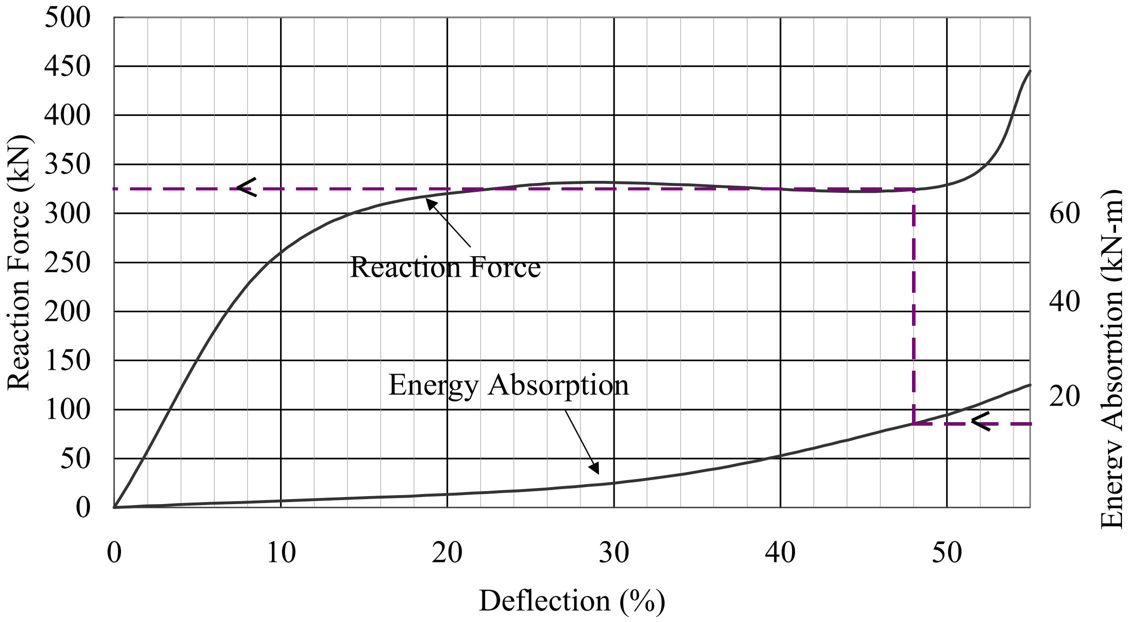
The total energy to be absorbed for accidental loading should be at least 50% greater than that for normal loading.

Therefore, select a rubber fender from the supplier's catalogue with design energy absorption capacity greater than 11.4 x 1.5 = 17.1 kNm

Since the pier has many fenders installed at a close spacing, the effect of angular compression on the fenders is neglected.

From the performance curve of the fender, the berthing reaction = 325 kN

Performance curve of fenders



A.2 Example 2

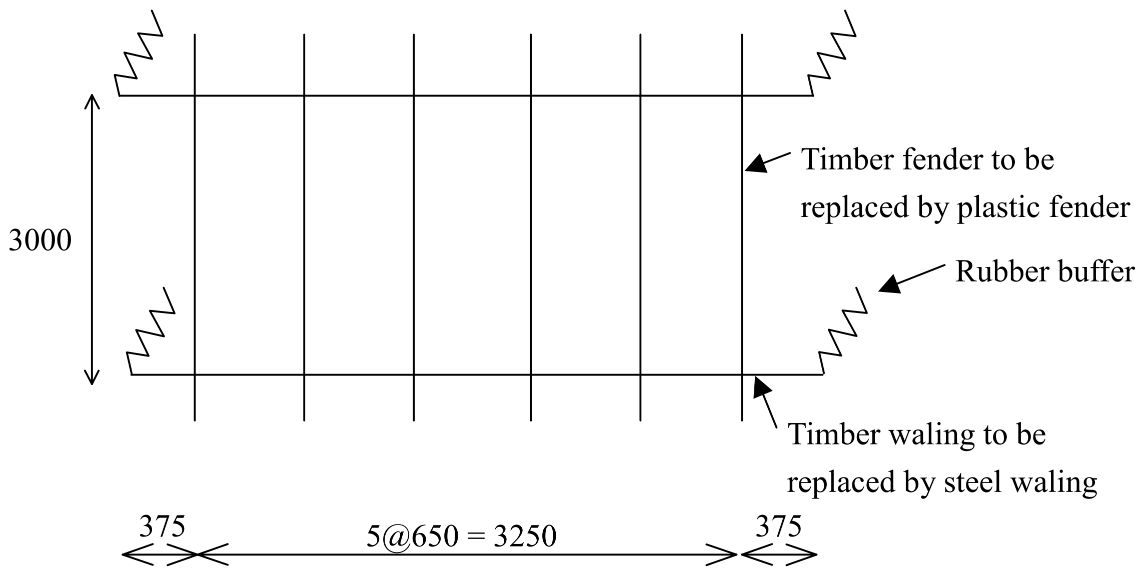
Given

The existing timber fenders of a piled deck ferry pier are to be replaced by plastic fenders. Determine the size of the plastic fenders, waling and rubber buffers. The design data are as follows:

Design vessel

Displacement	= 940 tonnes
Length	= 65.0 m
Beam	= 12.0 m
Depth	= 4.3 m
Draft	= 2.0 m

Existing fender frame



Dimensions in mm

Solution

(1) Try the following dimensions for the components of the fender frame

Plastic fender

Size = 300 mm x 300 mm

Modulus of elasticity, E = 32 Mpa

Moment of inertia, I = 0.0098 m^4

Bending stress, σ = 7 Mpa

Allowable moment = $\sigma I / y = 7 \times 10^6 \times 0.0098 / (0.3/2) = 457.3$ kNm

Rubber buffer

Cylindrical fender with outside diameter = 500 mm

Steel waling

Section = 356 x 406 x 340 kg/m Universal Column (Grade 43)

Modulus of elasticity, E = 200 MPa

Design stress = 265 Mpa

Plastic Modulus, S = 6.03×10^6 mm^3

Moment capacity = 265 x 6.03 = 1598 kNm

(2) Calculation of berthing energy

Assume the distance of the point of contact of the vessel from its centre of mass = 20m

Angle between the line joining the point of contact to the centre of mass and the velocity vector, $\gamma = 45^o$

V_b = 0.3 m/s

C_m = 1+2(2.0/12) = 1.33

K_v = $[0.19 \times 940 \times 10^3 / (65 \times 12 \times 2.0 \times 1025) + 0.11] \times 65 = 14.41$

C_e = $(14.41^2 + 20^2 \cos^2 45) / (14.41^2 + 20^2) = 0.67$

C_s = 1.0

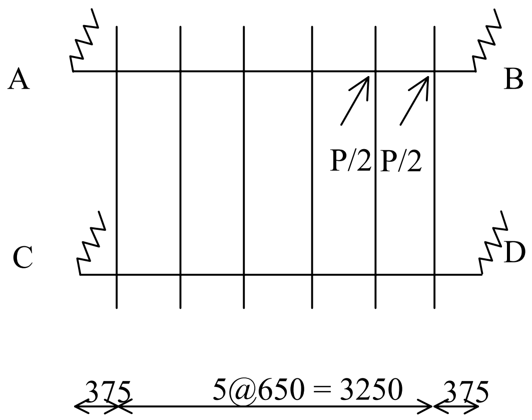
C_c = 1.0 for piled deck pier

Berthing energy = $0.5 \times (1.33 \times 940 \times 0.3^2 \times 0.67 \times 1.0 \times 1.0) = 37.7$ kNm

(3) Capacity of the fender frame

The capacity of the fender system is checked for the following load cases:

Load case 1: Berthing load at close proximity to the buffer

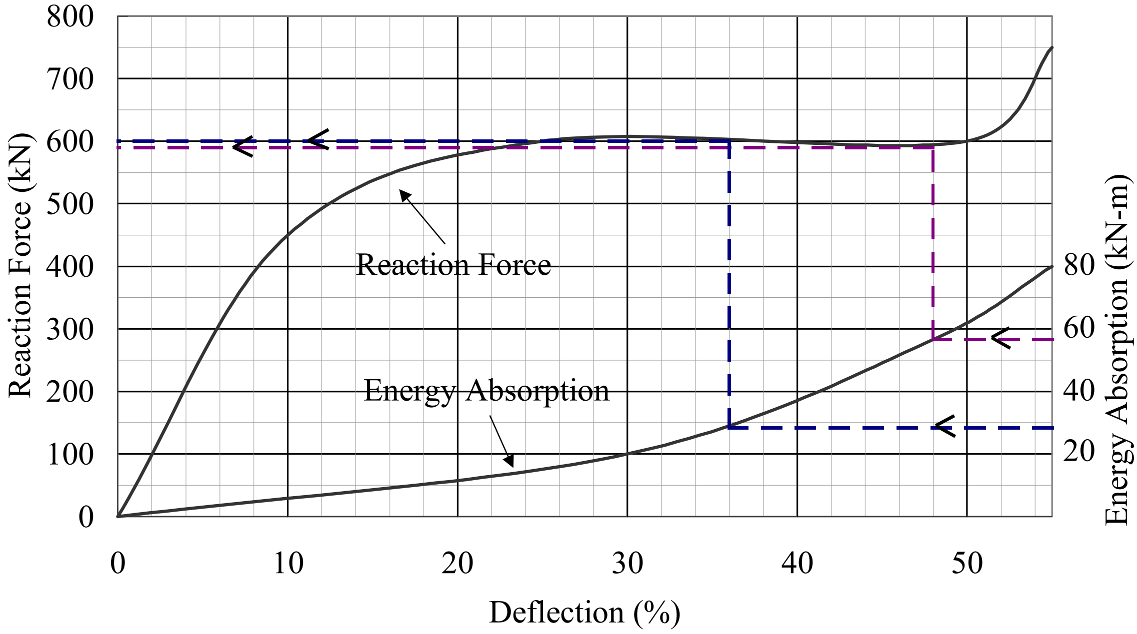


Let the berthing load be P.

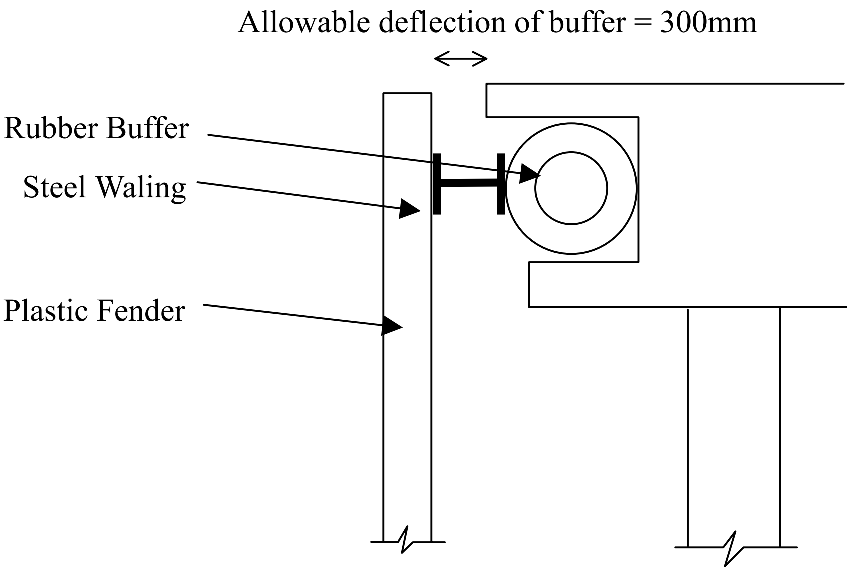
Assume that the design vessel collides with two fenders at one time and the berthing load P is equally shared between the two fenders. Since the berthing load P is very close to the buffer, it is assumed that all the berthing energy is absorbed by the buffer at B only. The total energy to be absorbed for accidental loading should be at least 50% greater than that for normal loading.

Berthing energy to be absorbed = 37.7 x 1.5 = 56.6 kNm

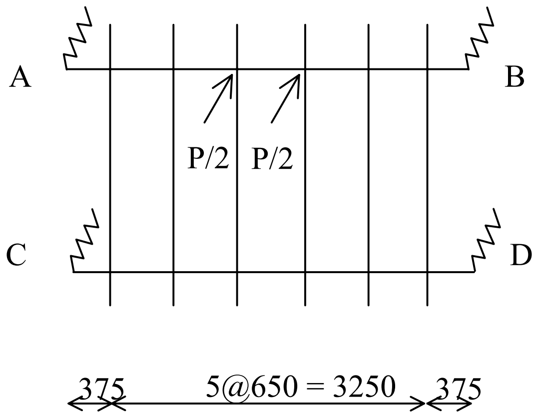
Performance curve of buffers

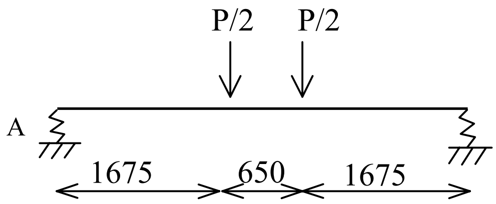


From the performance curve of the buffer,
Reaction force = 590 kN
Deflection = 48% x 500 = 240 mm < 300 mm



Load case 2: Berthing load at mid-span of steel waling





Assume that the total berthing energy is to be equally shared between two buffers (A and B). The total energy to be absorbed for accident loading should be at least 50% greater than that for normal loading.

Therefore, berthing energy to be absorbed by one buffer = 37.7 x 1.5 /2 = 28.3 kNm

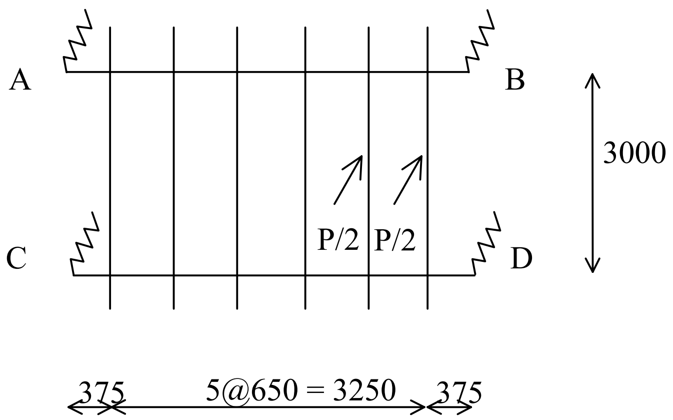
From the performance curve of the buffer, the reaction force at B = 600 kN
By symmetry, the reaction force at A = 600 kN and P/2 = 600 kN

Checking moment capacity of steel waling :
Maximum Moment in steel waling = 600 x 2 – 600 x 0.375 = 975 kN
Taking a load factor of 1.6 according to BS 5950
Factored moment = 1.6 x 975 = 1560 kNm (<1598 kNm, OK)

Checking deflection of steel waling
Allowable deflection = L/360 = 4000/360 = 11.1 mm
Actual deflection of steel waling at mid-span = 6.1 mm (<11.1 mm, OK)

Note : In principle, when the load is applied at the steel waling, there is some energy absorbed by the steel waling due to bending. When the load is at mid-span, this energy is approximately equal to 3.7 kNm (½ x 0.0061 x 600 + ½ x 0.0061 x 600). It is negligible in comparison to the total berthing energy of 56.5 kNm.

<u>Load case 3: Berthing load at mid-span of plastic fenders</u>



Similarly to load case 2, assume that the total berthing energy is equally shared between two buffers (B and D). Therefore, the reaction force at B = 600 kN
By symmetry, the reaction force at A = 600 kN and P/2 = 600 kN

Deflection of a plastic fender at mid-span
= $FL^3/16EI$ (where F is the applied load at mid-span)
= $(P/2)(3)^3/(16 \times 32 \times 10^6 \times 0.0098)$
= 3.3 mm

Maximum moment in one plastic fender
= (P/2)(3)/4
= 450 kNm (<457.3, OK)

Note : In principle, when the load is applied at the two plastic fenders, there is some energy absorbed by the plastic fenders due to bending. When the load is at mid-span, this energy is approximately equal 2.0 kNm (½ x 0.0033 x 600 + ½ x 0.0033 x 600). This is negligible in comparison to the total berthing energy of 56.5 kNm.