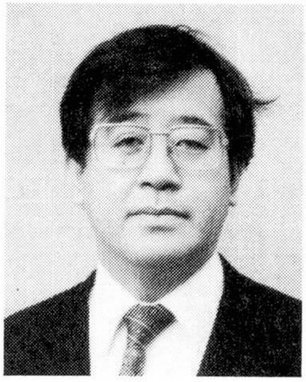
Case stories of dolphin accidents and remedies

Case Stories of Dolphin Accidents and Remedies
Accidents aux postes d'amarrage et remèdes
Zusammenstöße mit festen Bojen und Lösungen

Yoshiaki NAOI
Supervising Engineer
Chuo Fukken Consultants
Osaka, Japan

Toshiyuki ISHIKAWA
Chief Engineer
Chuo Fukken Consultants
Osaka, Japan

Yoshiaki Naoi, born in 1936, got his civil engineering degree at Ritsumeikan Univ. in 1960. Now a Certified Consulting Engineer, he works as a Supervising Engineer in the Investigation and Design Department of Harbour Structures.



Toshiyuki Ishikawa, born in 1946, got his civil engineering degree at Hokkaido Univ. in 1970. Now a Certified Consulting Engineer, he works as a Chief Engineer in the Investigation and Design Department of Harbour Structures.

SUMMARY
The report outlines recent ship collision accidents with dolphins in Iwakuni, Japan and their remedies.

RÉSUMÉ
Ce rapport traite d'accidents causés par la collision des cargos avec les postes d'amarrage à Iwakuni, Japon et ses remèdes.

ZUSAMMENFASSUNG
Es wird über Zusammenstöße mit festen Bojen in Iwakuni, Japan berichtet. Lösungen werden vorgeschlagen.

1. GENERAL

In and around the Japanese waters, marine accidents have occured frequently. About 2,300 vessels of which 50-60 % are foreign vessels meet with accidents and about 400 passengers and crewmen die or are missing annually.

Marine accidents are classified into ten types i.e. collision, stranding, engine trouble, fire, etc. and ship collisions are about 16 % of the total number of these marine accidents.

We have investigated ten cases of marine accidents, in which oil tankers and cargo vessels collided with dolphins. In the following pages two collisions which occured at Iwakuni, Yamaguchi Prefecture, Japan in 1978 and 1979 are investigated.

The harbour structure of concern here has a landing berth for wooden chips for paper-making and the berth was designed for foreign chip carriers with 53,600 dwt. As shown in Fig.1 the berth consists of 1 main-breasting dolphin, and 2 sub-breasting ones, and 4 mooring ones.

The north sub-breasting dolphin (B-3 in Fig.1) was damaged in the first collision in 1978, and the south mooring dolphin (M-1 in Fig.1) was again damaged in 1979.

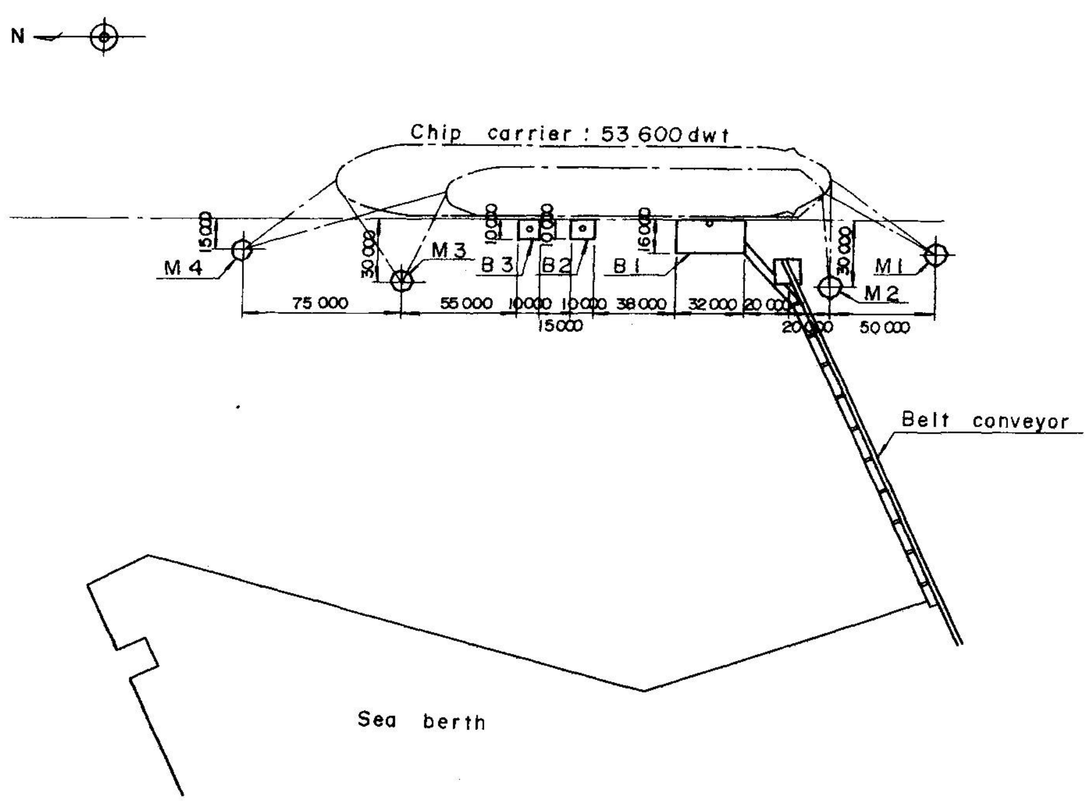


Fig.1 Outline Plan of the Berth

2. STRUCTURE OF THE DOLPHINS

2.1 Breasting Dolphin B-3

As shown in Fig.2 the Dolphin B-3 consists of 9 steel pipe piles (914.4 mm in diameter, 16.0 mm in thickness, and 41.5 m in length) and the top concrete deck. The structure has the flexibility to absorb the kinetic energy of ship berthing for an approaching velocity of 15 cm/sec. That is, the resisting capacity against impact is maintained by the mutual effect between the rigidity of the steel pipe piles and the viscoelasticity of the foundation strata.

2.2 Mooring Dolphin M-1

In the structure of the Dolphin M-1, 9 steel pipe piles (609.6 mm in diameter, 12.7 mm in thickness, and 40.5 m in length) composed of 8 radial battered piles and 1 vertical pile are rigidly connected with the top concrete deck. This mooring dolphin has a rigid structure in contrast with the breasting dolphin, that is, the static load worked through mooring ropes is borne by the structure so that a ship can keep a certain distance with the berth.

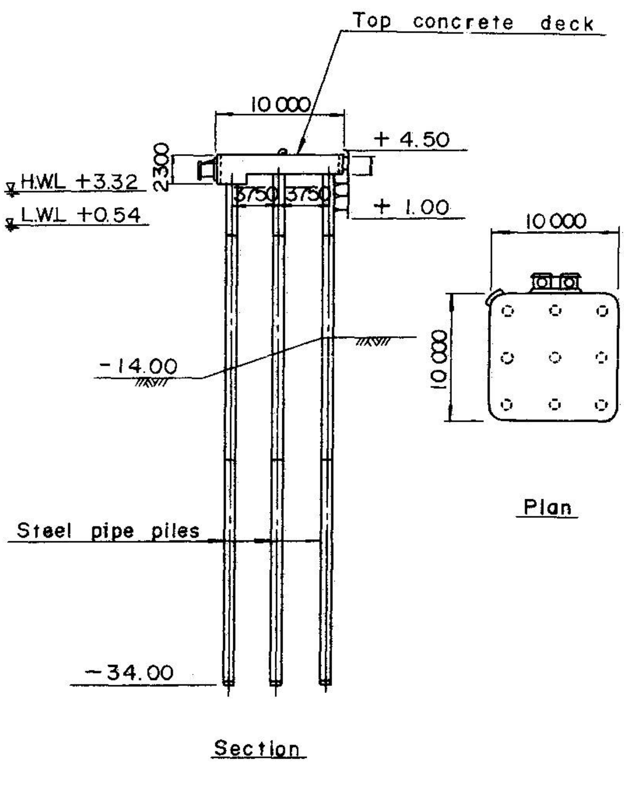


Fig.2 Structure of Dolphin B-3

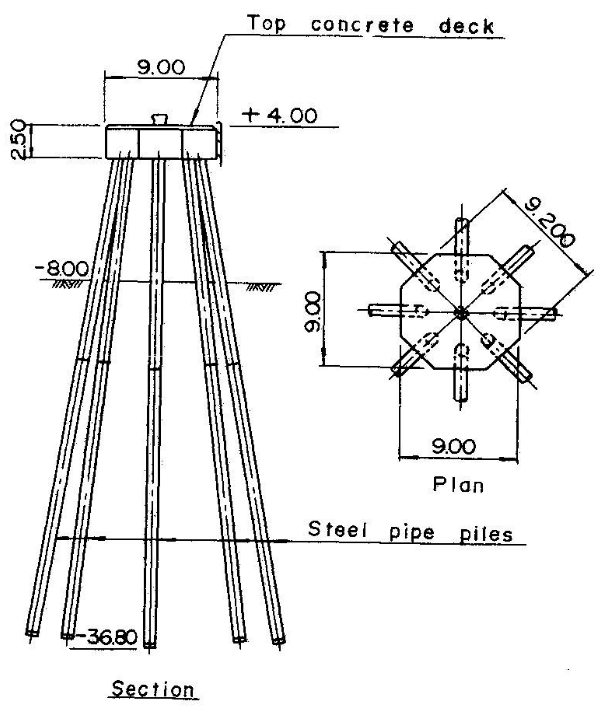


Fig.3 Structure of Dolphin M-1

3. CIRCUMSTANCES OF THE ACCIDENTS

3.1 The First Accident

The circumstances of the first collision accident in 1978 is described as follows: (See Fig.4)

While the vessel was approaching on her starboard side to the sea berth, the ship swung her stern towards the right side in order to maintain the correct direction for her berthing. After that, the side of the vessel collided with the fender on the corner of the north sub-breasting dolphin B-3.

The fender itself had no function to absorbe the impact energy of ships, therefore, the inertia force of the moving ship was directly loaded on the dolphin structure, and the foundation piles were deformed.

The particulars of the vessel were as follows:

Tonnage:	40,000 GRT
Length O.A.:	210 m
Breadth mld.:	30 m
Depth mld.:	20 m

3.2 The Second Accident

As in the first accident the same cargo vessel, in 1979, lost proper speed while she was approaching the berth from the north, then collided with the south mooring dolphin M-1.

Both collisions were caused by the mistakes of the operators. But, as described in the beginning of the article, Japanese coastal/offshore structures are located in very confused sea areas and it is one of the reasons of the frequent occurence of ship collision casualties.

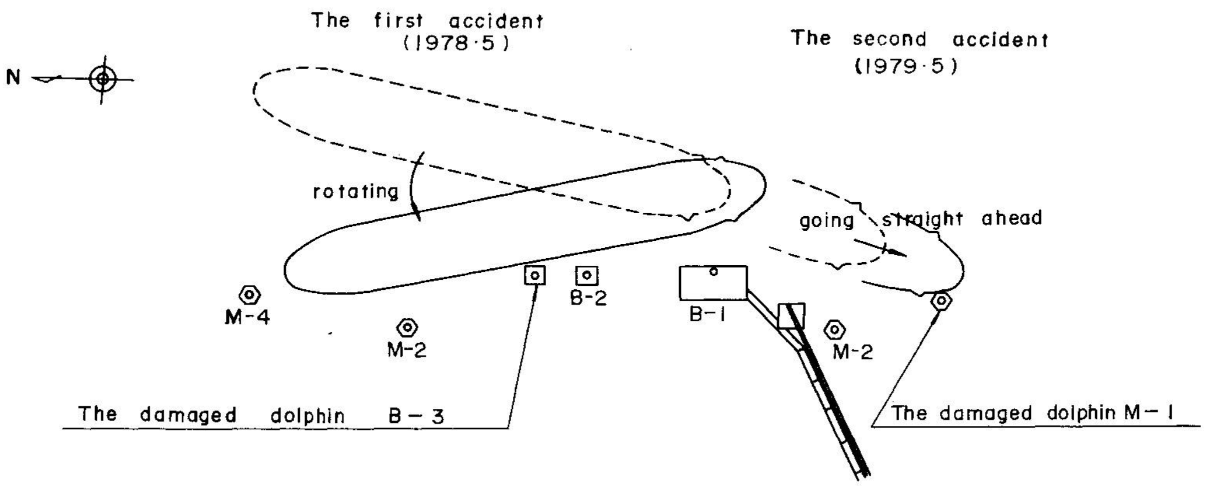


Fig.4 Geometry of the Collisions

4. DEFORMATION BY THE COLLISIONS

4.1 Breasting Dolphin B-3

The results of our inspection carried out immediately after the accidents are briefly as follows: (See Fig.5)

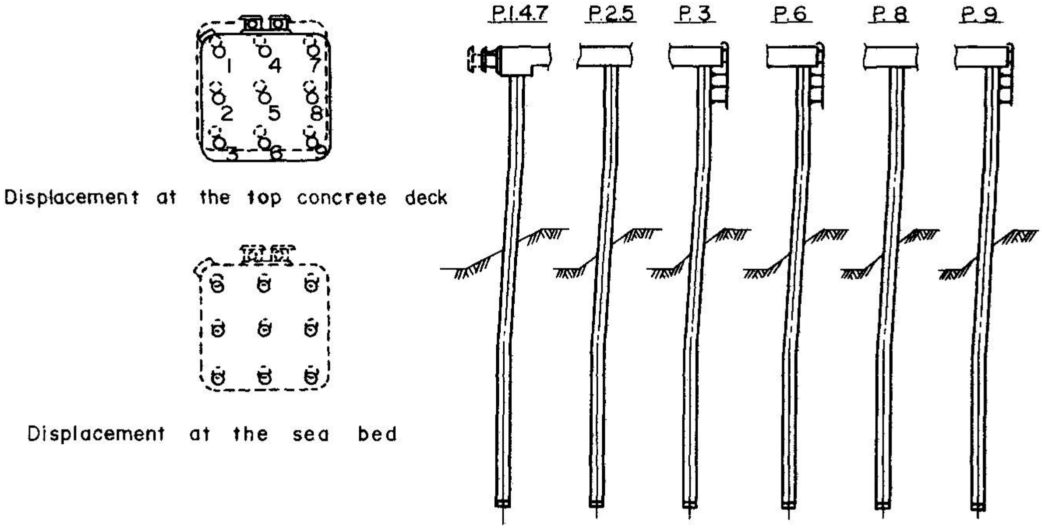


Fig.5 Deformation of Dolphin B-3

4.1.1 Deformation of the Top Concrete Deck

Upon measuring the damaged dolphin, the deformation was found to be the residual displacement of the top concrete deck:

Horizontal displacement:

In the direction of the berthing line ----- 25.2 cm
In the direction of right angle to the berthing line
----- 97.2 cm

Vertical displacement:

Inclination towards the shore on the diagonal line
----- 0° 20'

4.1.2 Deformation of the Steel Pipe Piles

Upon inspecting the piles in the water, the buckling on the piles were found near the welded joints of No.3,6,8 & 9 piles 2 m deep in the water and the shells thereon had been torn off.

The deformation by the collision was more severe on the opposite piles of the collision side. From that fact it was presumed that the dolphin was rotated by the collision impact (the horizontal force) so that those opposite piles were loaded by both the force at a right angle to the axes and the axial force (the compressive forces).

Further, the maximum deformation was found on the middle piles (12.7 mm in thickness) while the upper piles above D.L. -0.50 m were still vertical with little deformation. The reason for this is that the materials of the upper piles were thicker (16.0 mm in thickness) and they were stuffed with filling concrete.

4.1.3 Deformation of the Ground

After the diving inspection, voids of 40 cm in width and 100 cm in depth were observed in the sea bed on the offshore side of the piles. It indicated that plastic deformation in the ground occured by the energy exerted by the collision.

4.2 Mooring Dolphin M-1

4.2.1 Deformation of the Top Concrete Deck

An opening made by the collision was found at the junction of the top concrete deck with the steel pipe piles. This opening was 20 cm at its maximum in a direction of north-west. At the same time a wedge from the shearing force (1.6 m in width, 0.2 m in height, and 0.4 m in depth) appeared in the concrete deck.

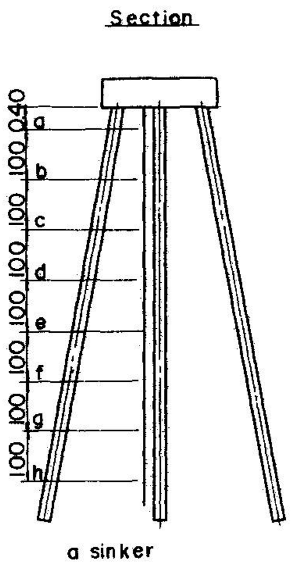
4.2.2 Deformation of the Steel Pipe Piles

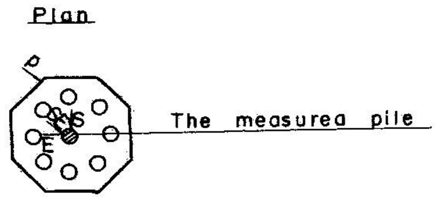
Upon measuring the deformation of the central vertical pile in three directions, the maximum displacement of 25 cm was observed in the direction of south-east. (See Fig.6)

Shells of barnacles and sea mussels had been torn off around the tidal zone at the top of the piles, and it indicated the hysteresis of deformation.

4.2.3 Deformation of the Ground

The sea bed was covered with mud so that deformation of the ground could not be inspected there.





Displacement

(Unit: m)

	S	E	SE
a	0.480	0.505	0.508
b	0.455	0.485	0.490
c	0.425	0.460	0.440
d	0.400	0.440	0.400
e	0.370	0.410	0.360
f	0.345	0.400	0.330
g	0.320	0.360	0.300
h	0.290	0.350	0.260
	0.190	0.153	0.248

Fig.6 Deformation of Dolphin M-1

5. METHOD OF RESTORATION

In the case when a structure receives an impact of excessive energy over the designed value, the structure cannot perfectly rebound to its original state but will have residual deformation and stress in itself even after removal of the load. It seems that the residual deformation is caused by both the change in the steel material which reaches the plastic range over its yield point and the plastic deformation of the ground.

From a technical point of view, as usual, it used to be said that a structure with residual deformation, whose material suffered stress hysteresis over its yield point, would be very dangerous if re-used. Especially for a remedy of a damaged dolphin which is constantly loaded with forces again and again, a dismantlement and re-construction method is generally adopted.

However, on the basis of an accurate stress analysis of the materials, we selected a reinforcement method with additional piles, in which the structural system of the dolphin was not changed but improved in order to keep its stability. That is, if the residual yield strength of a damaged structure with residual deformation is accurately estimated, the structure can be restored by redistribution of the stress from its reinforcement. (See Fig.7 & 8)

In conclusion, we assume that it will be more valid and of more general applicability to accurately estimate the residual function of the damaged structure in order to select a restoration method for the same structure, when the structure is not entirely destroyed by a collision.

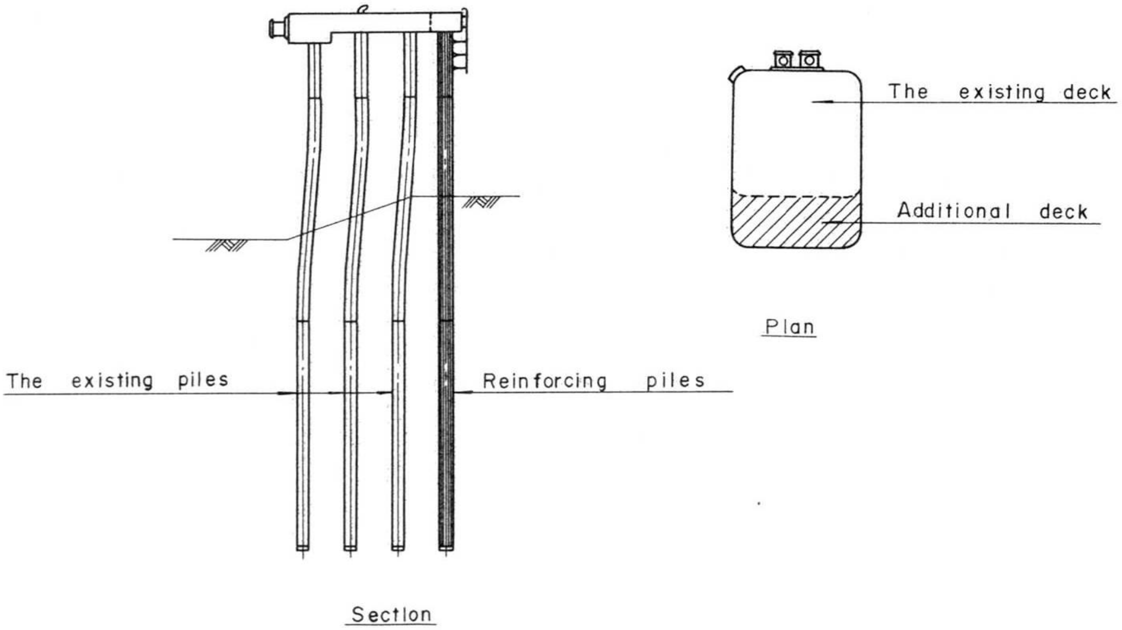


Fig.7 Restoration of Dolphin B-3

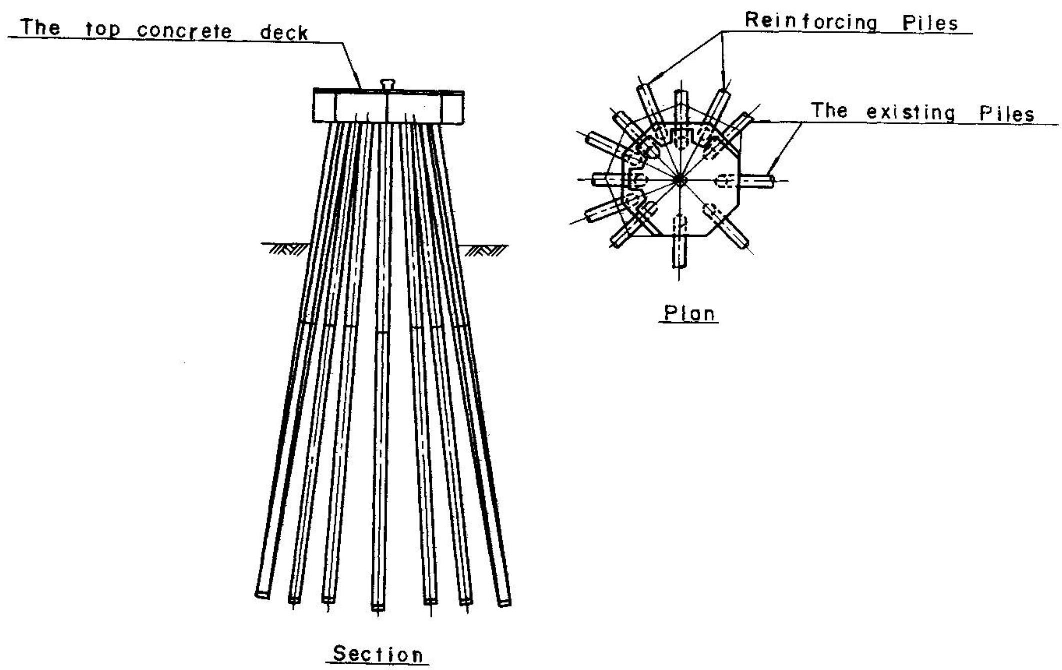


Fig.8 Restoration of Dolphin M-1

REFERENCES

1. MARITIME SAFETY AGENCY, JAPANESE GOVERNMENT: Guidance for the Safe Navigation, March 1982
2. OSAKA BAY FOREIGN VESSEL SAFETY CONFERENCE: Navigational Information, July 1982.