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Guidelines for the Maintenance of Rubber Fender Systems (2nd Edition)

September 2019

Coastal Development Institute of Technology

Preface

Port facilities must contribute to society by serving as a base for maritime transport that supports physical distribution. The Ordinance of MLIT for the Technical Standards for Port and Harbour Facilities amended in April 2007 requires the maintenance of the Port Facilities subject to the Technical Standards. Based on this Ordinance, the Manual for Maintenance Techniques of Port and Harbour Facilities compiling the basic concept for maintenance of port and harbour facilities was published by the Coastal Development Institute of Technology in October 2007.

The fender system plays a key role in the safe berthing of a vessel and in stable loading/unloading as auxiliary equipment at the mooring facility. When the fender system is damaged or degraded, considerable economic losses can occur due to suspension or restriction of the mooring facility, which may affect the operation and maintenance of the entire port and facility. Accordingly, it is necessary to detect damage and deterioration of the fender system in the early stages and to implement the appropriate measures according to a correct assessment of the functions of the fender system. Thus, the existing technical knowledge concerning the maintenance of fender systems was compiled and published as the Guidelines for the Maintenance of Rubber Fender Systems in July 2010. This book provides specific and easy-to-understand descriptions of the checks and diagnostic methods and the replacement methods of fender systems.

Since then, revisions have been requested, including knowledge and discoveries made from the investigation of the 2011 earthquake off the Pacific coast of Tohoku, which led us to create the second edition of these guidelines in March 2013.

It is my great pleasure to publish the English edition of this guideline, and I hope it will be widely disseminated to those involved in the maintenance of ports around the world and used for the maintenance of fenders.

高橋重雄

Shigeo Takahashi, President
Coastal Development of Technology
September 2019

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（Second Edition, 2013）

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（First Edition, 2010）

Guidelines for the Maintenance of Rubber Fender Systems (2nd Edition)

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Chapter 1
Introduction

1.1 General

1.1.1 Summery

This guideline arranges the deterioration forms and factors of rubber fenders as ancillary equipment used in mooring facilities and transportation facilities in ports and shows appropriate checks and diagnosis methods to evaluate their function. These methods are explained and clarified as the guidelines for the maintenance of rubber fenders.

The standards used in these guidelines and their abbreviations are as shown in Table 1.1.1.

Table 1.1.1 Standards and references for rubber fenders

Abbreviation	References
PHAJ technical standards	Ports and Harbours Association of Japan: Technical Standards and Commentaries for Port and Harbour Facilities in Japan
CDIT maintenance manual	Coastal Development Institute of Technology: Maintenance Guidelines for Maritime Fender Systems
SCOPE planning guidelines	Service Center of Port Engineering: Guidelines for the maintenance management plan of port facilities
PARI technical notes	K. Terauchi, T. Koizumi, S. Yamamoto, K. Hosokawa: The deterioration, actual state and the function evaluation of the rubber fender, No. 878, 1997

1.1.2 Scope

These guidelines apply to the maintenance and management of rubber fenders and other rubber materials used as protective equipment. These guidelines show the standard maintenance methods of rubber fenders so that facilities can satisfy the required performance over the service period.

(1) Application of these guidelines

Although the basic concept is indicated in the CDIT maintenance manual and the SCOPE planning guidelines, these guidelines offer a standard of rubber fenders for the purpose of augmenting these standards. It shows the method of maintenance management in detail.

The matters not described in these guidelines will be in accordance with the CDIT maintenance manual and the SCOPE planning guidelines.

(2) What these guidelines show

In mooring facilities, rubber fenders are installed as protection equipment to ensure the safe and smooth berthing and mooring of vessels, protect bridge piers and reduce damage to colliding vessels in harbour transportation. During the service period of facilities, equipment such as rubber fenders is usually damaged or deteriorated by various external actions, and this deterioration is usually evident.

To use these facilities as a high-quality social infrastructure for a certain period of time, proper maintenance is essential for facilities that maintain functions and performance that satisfy a required level during the service period.

Maintenance management in these guidelines refers to a series of systems that detect deterioration of rubber fenders effectively, evaluate it rationally, and take effective measures. The basis of maintenance shown in these guidelines is represented by the following four items. Definitions of terms are shown in 1.1.3.

Checks and diagnosis: The act of quantitatively assessing the condition of rubber fenders, the state of deterioration, etc. mainly using periodic or temporary checks.

Function evaluation: The act of judging the degree of deterioration of rubber fenders based on the checks and diagnosis results.

Countermeasures: Maintenance, repair, removal, replacement work, etc., which will be carried out on rubber fenders based on the results of function evaluation, and measures such as restriction and/or suspension of operation that will be carried out for the whole facility.

Comprehensive evaluation: These guidelines show the functional evaluation of rubber fenders and measures taken based on the results. For a comprehensive evaluation of the entire facility, follow the CDIT maintenance manual and the SCOPE planning guidelines.

(Note)
In mooring facilities, rubber equipment such as rubber ladders, corner protectors, rubber nets and the like are used as other rubber materials in addition to fenders. These items are not classified as rubber fenders in Table 1.2.1, because they have less function of converting berthing energy into the energy absorption of fenders. Since they are used as incidental equipment, it is necessary to perform the same maintenance management as fenders.

1.1.3 Definition of terms

The terms used in these guidelines are defined as follows.

Rubber fender (Marine rubber fender): A generic term that includes accessories such as a rubber body and fixing anchor, supporting parts, and fender panels.

Maintenance: A generic term for the action of maintaining the required performance and function of rubber fenders above a standard.

Design service life: A period of time that continues to meet the required performance of a mooring facility or a port transportation facility design.

Service life: The life of equipment, such as rubber fenders, in mooring facilities and in harbour transportation facilities.

Function of Marine rubber fender: The role that a rubber fender should play according to purpose or demand.

Performance of Marine rubber fender: The performance that a rubber fender holds to satisfy its function.

Performance requirement: Performance required for the entire facility or for rubber fenders.

Durability of Marine rubber fender: The ability to resist the deterioration of the function and performance of a rubber fender over time.

Check: The act of inspecting, diagnosing, and quantitatively assessing the condition of rubber fenders, the state of deterioration, and functional deterioration.

Damage: Deterioration of rubber fenders that occurs suddenly due to accidental action (abnormal berthing or excessive vessel motion, etc.) or action not considered in design.

Ageing: The function and performance of a rubber fender decreasing over time due to the natural environment

and fatigue caused by use.

Deterioration: A generic term for defects such as damage to rubber fenders. Deterioration includes natural environmental deterioration, chemical deterioration, fatigue deterioration, and external force deterioration.

Mode of deterioration: Drops, tears, permanent deformations, missing rubbermissing rubber, cracks, chipping, separation, wear, ozone cracks, burns, damage to bolt holes, fractures that occur in the rubber body and deterioration on accessories such as looseness, missing, bending, cutting, or corrosion.

Damage rate: The ratio of damage length or damage area to the length or area of fender facing.

Deterioration rank: The degree of deterioration of the rubber body and accessories such as fixing parts and fender panels. The daily checks of the rubber body and the checks and diagnoses of all accessories are judged in four stages: a, b, c and d.

Deterioration score: The degree of deterioration of the rubber body. The score is judged by a point system of 0-12 in the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis.

Deterioration level: The degree of deterioration occurring in the body of a pneumatic fender. The level is judged in 6 stages, from I to VI, in the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis.

Degree of airtightness maintenance: The degree of airtightness of the air filled in the body of a pneumatic fender. The degree is judged in 4 stages, from I to IV, in the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis.

Corrective maintenance: Accepting the deterioration of function due to deterioration of rubber fenders to some extent and addressing deterioration with ex post measures by taking one or two large-scale measures during the service period of the equipment.

Life-cycle cost: The total cost of a series of processes such as planning, design, construction, maintenance, dismantling and removal of rubber fenders.

1.2 Classification of rubber fenders

1.2.1 General

Rubber fenders can be classified as follows according to the form of absorbing the berthing energy of the vessel.

(1) V-type rubber fender
(2) Rubber fender with fender panel
(3) Pneumatic fender
(4) Cylindrical rubber fender

Rubber fender classification is summarized in “Guidelines for the Design of Fender Systems” [1)]. Table 1.2.1 shows images of the shape, size, reaction force, energy absorption and performance curve for each type of rubber fender generally used.

(1) V-type rubber fender

A V-type rubber fender is in direct contact with the rubber surface of the fender body and absorbs the berthing energy of the vessel by buckling deformation of the rubber body. Therefore, it is necessary to pay

attention to the deterioration of rubber due to external force.

(2) Rubber fender with fender panel

A rubber fender with the fender panel brings the vessel into contact with a steel fender panel and absorbs the berthing energy of the vessel by means of buckling deformation of the rubber body. Since the vessel does not come in direct contact with the rubber, the damage and breakage of the rubber body is slight, but care must be taken for the corrosion and deformation of the steel fender panel.

(3) Pneumatic fender

A pneumatic fender is a fender that absorbs the energy of the berthing vessel by the elasticity of air filled in the rubber body and is classified as either a floating pneumatic fender or a fixed pneumatic fender with a fender panel. The floating air fender is generally protected by a net, so damage and breakage of the rubber main body is slight, except for the deterioration of the net. The fixed air fender with a fender panel is a fender similar to a rubber fender with a fender panel, and attention must be paid to the corrosion and deformation of the steel.

With any pneumatic fender, care must be taken to maintain pressure resistance and control air pressure.

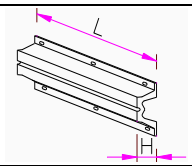
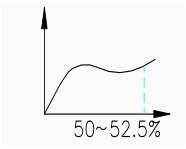
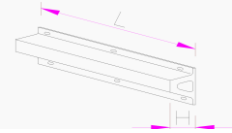
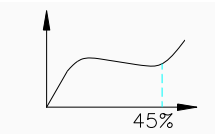
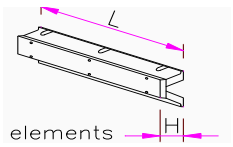
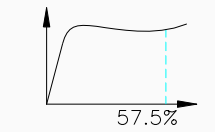
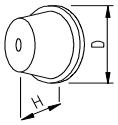
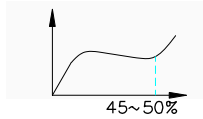
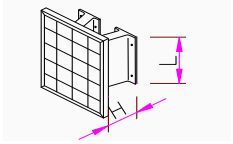
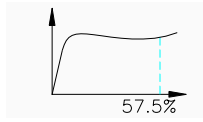
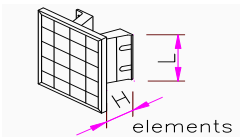
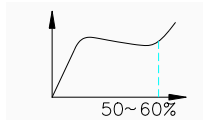
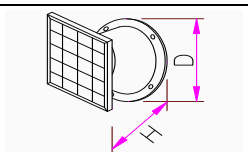
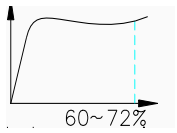
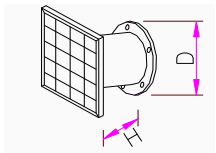
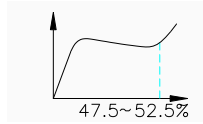
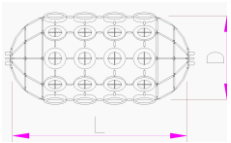
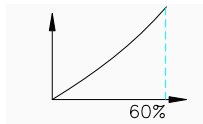
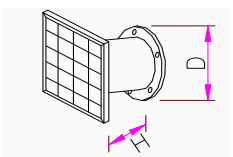
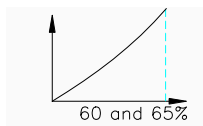
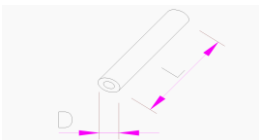
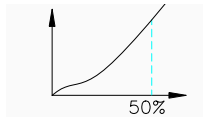
(4) Cylindrical rubber fender

In a cylindrical rubber fender, because the vessel is in direct contact with the rubber body and absorbs the berthing energy of the vessel by deformation of the rubber, it is necessary to pay particular attention to deterioration by external force.

(Note)

Chapters 2 and 3 of these guidelines show the standard maintenance practices that apply to rubber fenders. In addition, the standard maintenance method implemented for other peripheral rubber products is also shown.

Table 1.2.1 Overview of different types of rubber fenders

		Shape	Size (mm)	Reaction force (kN)	Energy absorption (kN·m)	Performance (Rated deflection %)
Buckling-type fender with direct contact	Longitudinal V-type fender		H/L 250/1000 ↓ 1000/2000	150 ↓ 2290	15 ↓ 940	
			H/L 200/1000 ↓ 1300/3500	150 ↓ 3400	10 ↓ 1500	
			H/L 300/600 ↓ 1000/2000	45 ↓ 646	6 ↓ 297	
	Circular V-type fender		D/H 600/300 ↓ 2065/1150	39 ↓ 1300	4 ↓ 577	
Buckling-type fender with panel contact	Longitudinal shape with panel		H/L 300/600 ↓ 1800/2000	66 ↓ 1708	9 ↓ 1260	
			H/L 400/500 ↓ 2500/4000	140 ↓ 6900	10 ↓ 7000	
	Circular shape with panel		D/H 500/300 ↓ 3200/2000	60 ↓ 4660	9 ↓ 4840	
			D/H 650/400 ↓ 3350/3000	56 ↓ 5688	22 ↓ 6570	
Pneumatic fender	Floating pneumatic fender		D/ L 500/1000 ↓ 4500/12000	50 ↓ 10570	4 ↓ 9080	
	Pneumatic fender with panel		D/H 600/450 ↓ 3200/3200	138 ↓ 6210	15 ↓ 4990	
Cylindrical rubber fender			D/L 150/1000 ↓ 2800/5800	80 ↓ 6600	3 ↓ 5000	

1.2.2 Name of each part

The names of each part of the rubber fender are as follows.

(1) Rubber body

Main rubber body: The main rubber body refers to a portion made of only rubber material. In pneumatic fenders, it refers to the inner layer, reinforcing layer, and outer layer that hold air pressure.

Fixing flange: The part that attaches the rubber body to the quay or fender panel. An embedded steel plate is installed in this part.

Embedded steel plate: The steel plate that is installed to maintain the strength of the fixing flange.

(2) Accessories

Fixing parts: Steel parts for attaching the rubber body to a quay or fender panel, consisting of anchors, bolts, nuts, washers, etc.

Fender panel: A steel fabricated frame installed on the front (vessel side) of rubber fenders. Since the contact area between the rubber fender and vessel hull becomes large, it can uniformly transmit the reaction force generated in the rubber fender to the vessel hull without direct contact of rubber and hull, so it can cope with the berthing of various vessel types. Thus, it is used to reduce damage to the rubber body.

Support parts: The metal parts installed in a fender with a fender panel to hold the weight of the fender panel and constrain the displacement of the fender panel as much as possible when the vessel is berthing. Includes U anchors, brackets with eye plates, chains, turnbuckles, hackles, shock-absorbing devices and so on.

Resin pad: A resin plate equipped on the surface where a steel fender panel comes in contact with vessel hull.

Air inlet valve: A valve for air inlet/exhaust equipped on a pneumatic fender.

Mooring parts: Fitting parts for mooring floating-type pneumatic fenders. Includes U anchors, brackets with eye plates, chains, shackles, rubber sleeves, etc.

Net: Accessory installed for the purpose of protecting the rubber body of a floating pneumatic fender. Includes chains, wire ropes, rubber sleeves, used tyres, etc.

1.3 Method of maintenance management for rubber fenders

1.3.1 General

The rubber fender should have its function properly maintained based on the maintenance plan so that a mooring facility and port transportation facility will meet the required performance over a service period. In the maintenance and management of rubber fenders, the conditions under which equipment is placed, such as natural conditions and usage conditions, structural characteristics, material characteristics, etc. are taken into consideration.

After appropriate checks and diagnoses of damage and deterioration to rubber fenders, such as ageing and functional evaluation based on the results, necessary measures will be appropriately performed.

(1) Necessity of the maintenance management plan

Rubber fenders are typically used while maintaining their required function for a long period of time. For this purpose, it is essential not only to consider the initial design of the rubber fenders but also to properly maintain the facilities in operation.

Since rubber fenders are used under harsh natural conditions, they need to be maintained and managed in a planned and appropriate manner because their functions will deteriorate during the service period of the facility due to material damage, ageing and so on. In accordance with the flow chart in Fig. 1.3.1, it is standard procedure to predetermine basic plans and methods such as checks and diagnoses, contents, timing, frequency, procedures, etc. as maintenance management plans at the start of maintenance. Maintenance management plans will be prepared in accordance with the SCOPE planning guidelines.

(2) Conditions and characteristics of maintenance and management

For maintenance and management of rubber fenders, it is necessary to plan appropriately in consideration of the characteristics of the members constituting the materials, difficulty of checks, the types and quality of the used materials, the natural conditions surrounding the equipment, usage importance, future plans of facilities, diagnosis, substitution and countermeasure work.

(3) Necessary measures

Maintenance and management of rubber fenders refers to a series of procedures for accurately grasping damage and deterioration over time by appropriate checks and diagnoses, comprehensively evaluating the results, and taking appropriate measures.

As a result of the functional evaluation of rubber fenders, the necessary measures are standardized to restore function or replace but also include operational measures of restriction and emergency measures for securing safety.

The basic flow for implementing maintenance efficiently and accurately is shown in Fig. 1.3.1.

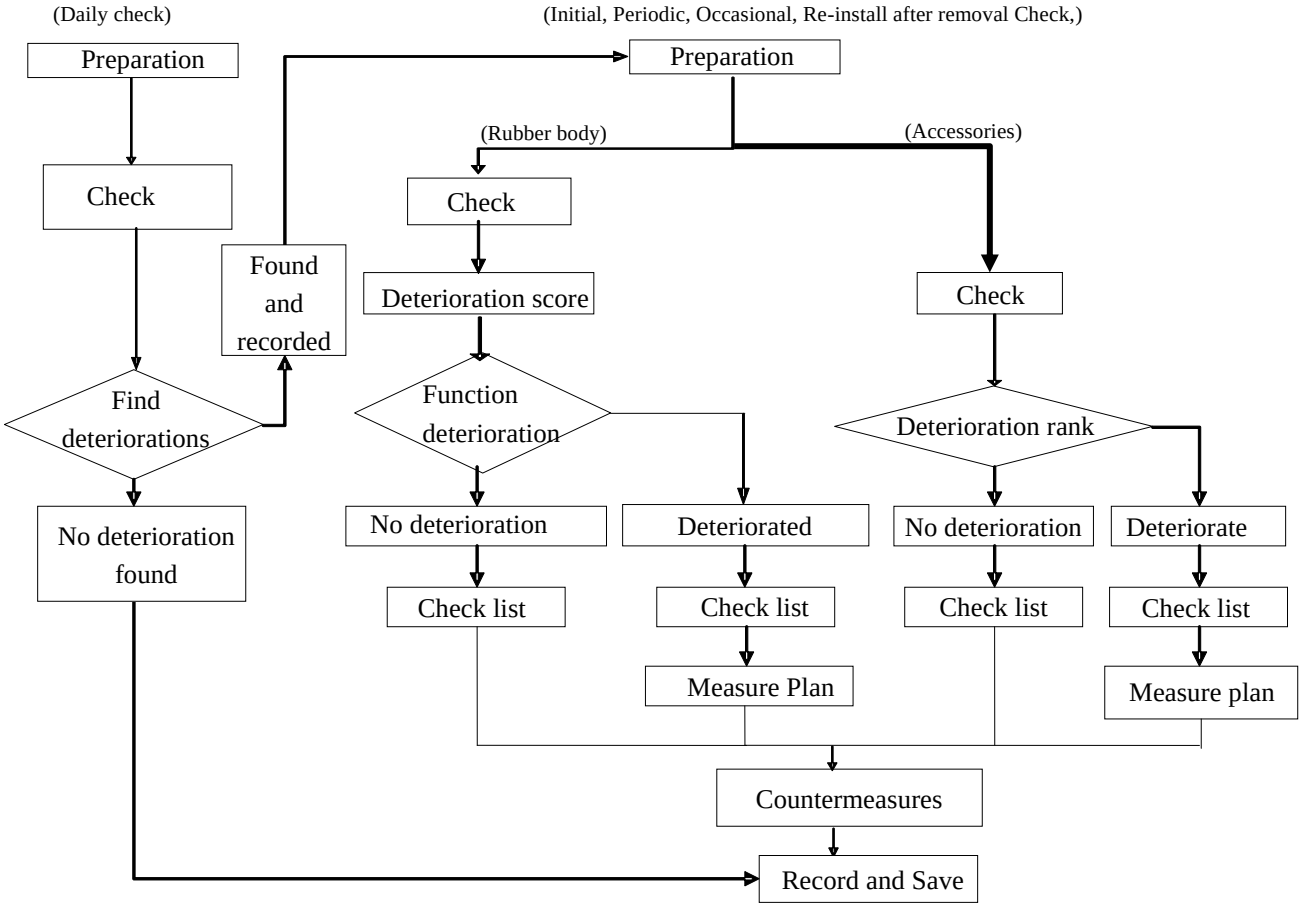


Fig. 1.3.1 The basic flow for implementing maintenance

1.4 Checks

1.4.1 General

To efficiently detect the deterioration that occurs in rubber fenders, it is necessary to perform planned and appropriate checks and diagnoses. The checks and diagnoses of rubber fenders include an initial check and diagnosis, a daily check, a periodic check and diagnosis, and an occasional check and diagnosis depending on the purpose and implementation timing. In the implementation of checks and diagnoses, to ensure the objectivity, reliability and consistency of the results, check and diagnosis items, check and diagnosis methods, and judgement criteria must be defined in advance.

(1) Checks and diagnoses

For the proper maintenance and management of rubber fenders, planned and periodical checks and diagnoses are essential, and the methods and results need to reliably evaluate the function of the rubber fenders.

(2) Classification of checks and diagnoses

The checks and diagnoses of rubber fenders are classified into initial check and diagnosis, daily check , periodic check and diagnosis, and occasional check and diagnosis, as shown in Fig. 1.4.1, depending on the purpose and time of implementation.

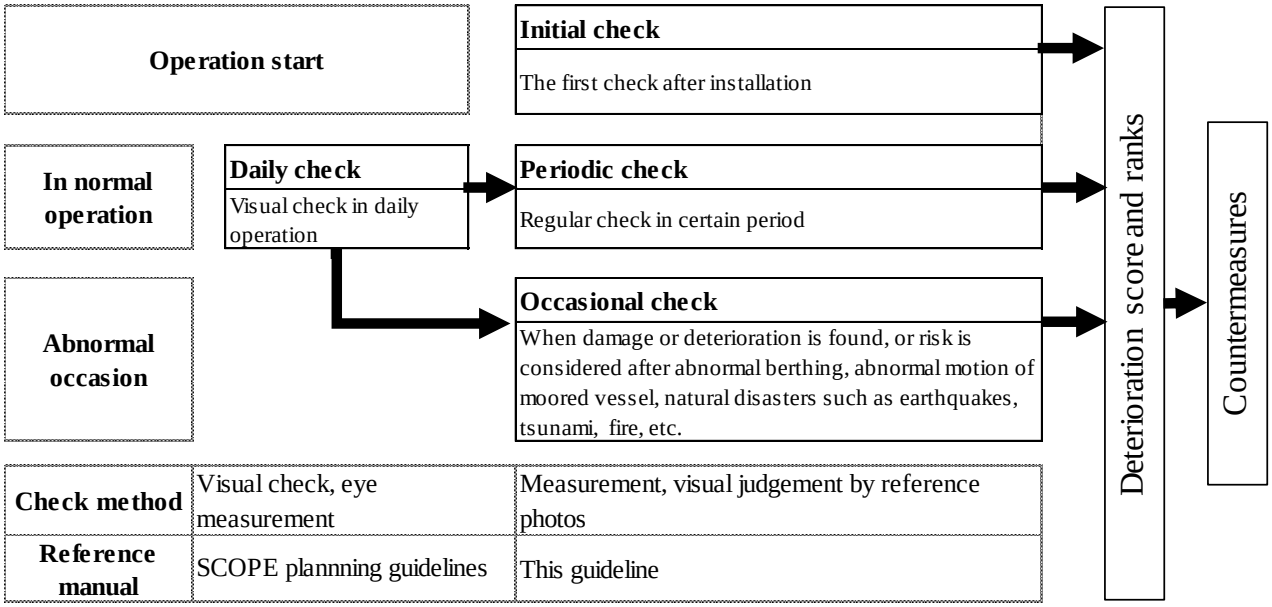


Fig. 1.4.1 Classification of checks and diagnoses

(3) Items for checks and diagnoses

The check and diagnosis methods and deterioration scoring methods for ensuring the objectivity, reliability and consistency of the inspection results are presented in Chapter 3. In principle, it is desirable to conduct checks and diagnoses in accordance with this method and to objectively evaluate the impact on the function of rubber fenders. On the other hand, inspections take place at height in a marine environment, and it is necessary to consider safety and balance the cost and performance required for periodic and occasional inspections.

The items for checks and diagnoses for rubber fenders are shown in Table 1.4.1, and other rubber equipment items are shown in Table 1.4.2.

Table 1.4.1 Items for checks and diagnoses for rubber fenders

		Deterioration mode	V-type fender	Rubber fender with panel	Pneumatic fender		Cylindrical
					Floating	With panel	
Rubber body		Drops	○	―	―	―	○
		Tears	○	○	―	―	○
		Permanent deformation	○	○	―	―	―
		Missing rubber	○	―	―	―	○
		Cracks	○	○	○	○	○
		Chipping	○	―	○	―	○
		Separation	○	○	○	○	―
		Wear	○	―	○	○	○
		Ozone cracks	○	○	○	○	○
		Cuts	―	―	○	○	―
		Burns	○	○	○	○	○
		Bolt hole damage	○	○	―	○	―
Accessories	Fixings	Loose	○	○	―	○	―
		Bent	○	○	―	○	―
		Missing	○	○	―	○	―
		Cut	○	○	―	○	―
		Corroded	○	○	―	○	―
	Supports	Bent	―	○	―	○	○
		Cut	―	○	―	○	○
		Corroded	―	○	―	○	○
	Fender panel	Deformation	―	○	―	○	―
		Corrosion	―	○	―	○	―
	Resin pad	Abrasion, Wear	―	○	―	○	―
		Cut	―	○	―	○	―
		Missing	―	○	―	○	―
		Burned	―	○	―	○	―
	Mooring parts	Bent	―	―	○	―	―
		Cut	―	―	○	―	―
		Corroded	―	―	○	―	―
	Others (Net, Air inlet, etc.)	Injury	―	―	○	○	―
		Corrosion	―	―	○	○	―
		Cut	―	―	○	―	―
		Crack	―	―	○	―	―
		Wear	―	―	○	―	―

Table 1.4.2 Items for checks and diagnoses other rubber equipment

Deterioration mode \ Product		Rubber ladder	Corner protector	Rubber net
Rubber body	Drops	○	—	—
	Tears	○	—	—
	Permanent deformation	○	○	—
	Missing rubber	○	○	—
	Cracks	○	○	—
	Chipping	○	○	—
	Separation	○	○	—
	Wear	○	○	—
	Ozone cracks	○	○	—
	Cuts	○	—	○
	Burns	○	○	○
	Bolt hole damage	○	○	○
Fixings	Loose	○	○	○
	Bent	○	○	○
	Missing	○	○	○
	Cut	○	○	○
	Corroded	○	○	○

1.4.2 Initial check

The initial checks are conducted to assess the condition of the rubber fenders immediately after installation or at the start of the maintenance stage. It is ideal to use a scale for measurement, but when this is difficult, measurement by visual observation may be acceptable.

1.4.3 Daily check

The daily check is a routine inspection of a rubber fender to assess the deterioration of the fender by daily protocol. If deterioration is detected, it is necessary to proceed to the implementation of occasional inspection and diagnosis. The daily check corresponds to a protocol that a manager or user of fenders carries out on a daily basis and is carried out to pay regular attention to any damage or deterioration. The inspection method in this case may be visual inspection by walking.

1.4.4 Periodic check

Periodic checks and diagnoses are conducted regularly to determine any deterioration, with the aim of detecting the occurrence as quickly as possible and any progress of deterioration caused by the use of rubber fenders. Periodic checks and diagnoses should be carried out systematically and continuously based on a predetermined inspection plan. They should be conducted at least once a year or planned appropriately according to the importance of the facility.

It is desirable to use a scale for measuring and determining the deterioration of a fender, but if this is difficult, visual measurement may be used.

1.4.5 Occasional check

Occasional checks and diagnoses are conducted to confirm the damage of fenders when deterioration is recognized during daily inspection, abnormal berthing, excessive vessel motion, etc., or when there is a possibility of being

affected by an earthquake, tsunami, fire, etc.

In carrying out occasional checks and diagnoses, it is necessary to measure the deterioration that has occurred in the rubber fender according to the periodic check and diagnosis and confirm the degree of deterioration.

1.5 Functional evaluation and measures

1.5.1 General

Based on the check and diagnosis results, functional evaluation is performed based on the determination of the deterioration score and deterioration rank of the rubber fenders, and appropriate measures should be considered. In functional evaluation, damage and deterioration over service time is examined in each rubber fender to determine how it occurred, how it progressed and whether to consider measures be taken as necessary.

1.5.2 Functional evaluation

In the functional evaluation of rubber fenders, deterioration rank and deterioration score are determined based on check and diagnosis results. During daily inspection, the deterioration rank is judged in four stages—a, b, c and d—based on the CDIT maintenance manual. If the deterioration rank is a, occasional inspection and diagnosis must be conducted. The initial check and diagnosis, periodic check and diagnosis, and occasional check and diagnosis parameters are based on this guideline. For the rubber body, the deterioration score is calculated by measuring the damaged parts, and for accessories, the deterioration rank is determined by a visual condition of each part.

Chapter 3 shows how to determine the degradation rank and degradation score of the rubber fenders.

1.5.3 Countermeasures

Based on the results of the functional evaluation, appropriate measures are implemented as necessary. If it is determined that some measures are necessary now or in the future, it is necessary to make a plan of measures after taking into consideration the service period of the facility and necessary costs in the future. Chapter 4 outlines these measures.

In making comprehensive judgements after checking and diagnosing leading up to countermeasures, past records of the conditions and technical knowledge about countermeasures at other ports are helpful.

1.5.4 Life-cycle cost

To maintain rubber fenders effectively and economically, it is desirable to consider the life-cycle cost related to the maintenance of the entire facility to appropriately maintain rubber fenders. If the function of the fender decreases due to deterioration, it may be necessary to suspend the operation of the mooring facility and port traffic facility, which may cause a loss due to the operation shutdown of the facility. Therefore, the proper maintenance and management of rubber fenders contributes to the optimization of the life cycle cost of the entire facility.

The life cycle cost of the entire facility shall be considered in accordance with the CDIT maintenance manual.

1.6 Recording and saving data

It is necessary to record and save various data related to the maintenance of checks and diagnoses, functional evaluations, measures, etc. according to a certain format. These maintenance management records are basic information for performing appropriate evaluations and measures of fender function and are useful for the maintenance management of other similar facilities.

〔References〕

1) PIANC : Guidelines for the Design of Fenders System, Report of Working Group 33 of the Maritime Navigation Commission, 2002

Chapter 2
Deterioration factor and deterioration mode of rubber fenders

2.1 Summary

2.1.1 General

The degradation factor of rubber and deteriorating factors of accessories must be considered. The deterioration factors of rubber fenders are classified into natural environmental factors, chemical factors, fatigue factors, and external force factors.

(1) Rubber deterioration phenomena and factors

The deterioration factors of rubber include natural environmental factors, chemical factors, fatigue factors and external force factors. A systematic summary of deterioration factors and phenomena is shown in Fig. 2.1.1 [1)].

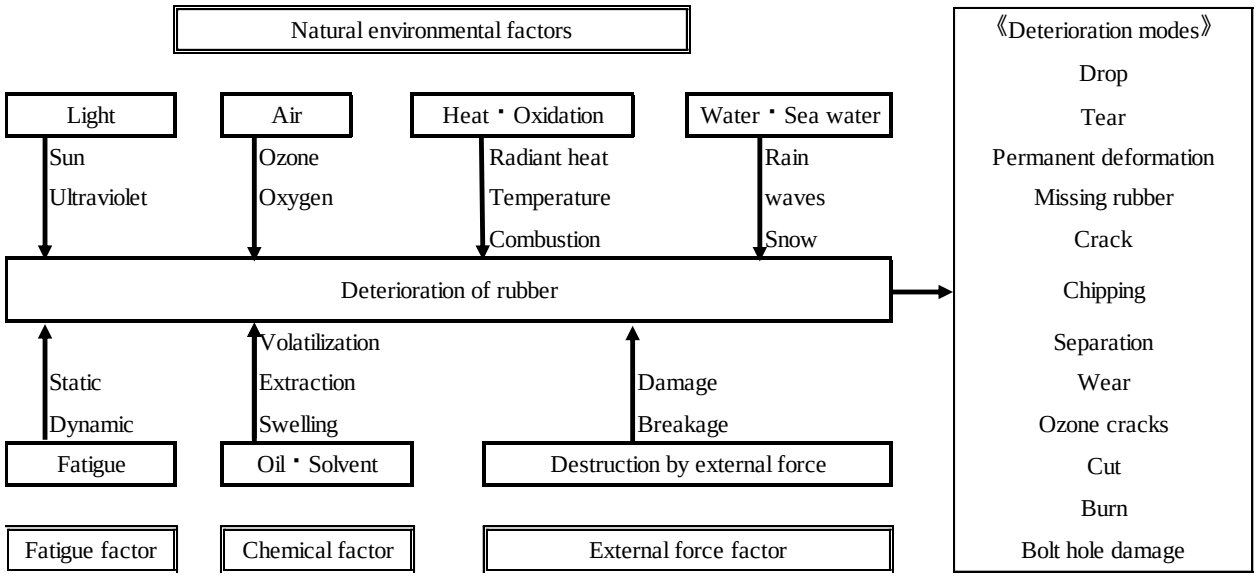


Fig. 2.1.1 Deterioration phenomenon and factors of rubber

(2) Deterioration phenomena and factors of accessories

There are natural environmental factors, chemical factors, fatigue factors and external force factors involved in the deterioration of accessories. These accessories include steel members (fixing parts, supporting parts, fender panels, anchoring parts), resin pads and so on.

2.1.2 Deterioration factors of rubber fenders

The deterioration factors of rubber fenders are categorized as deteriorations of rubber bodies and accessories.

(1) Deterioration factor of rubber body

1) UV (Ultraviolet) deterioration

Ultraviolet light in sunlight has a wavelength of 290 to 400 nm and provides energy for dissociating bonds of organic compounds, and this dissociation is called ultraviolet light deterioration. UV deterioration is significantly accelerated in the presence of oxygen, such as thermal and oxidative deterioration. Therefore, ultraviolet deterioration occurs only on the surface where oxygen is present and the ultraviolet light directly strikes. Since rubber fenders contain carbon black, ultraviolet rays do not reach inside the rubber, and deep parts of the body are less likely to be deteriorated by ultraviolet rays.

2) Ozone deterioration

Ozone contained in the air reacts with unsaturated double bonds in rubber to cause cleavage of the molecular chain. When rubber is used in tension, sharp cracks similar to razor cuts occur on the surface. This phenomenon is called ozone cracking (ozone deterioration). In the case of rubber fenders, since diene rubber, such as natural rubber (NR) or styrene butadiene rubber (SBR), is used, ozone deterioration is limited to the surface in contact with ozone in the air.

3) Thermal and oxidative deterioration

When rubber is maintained for a long time at a certain temperature with oxygen, the autoxidation reaction of the polymer progresses. The phenomenon where rubber materials change, such as deterioration due to autoxidation reaction, discoloration, cracks, etc., is called thermal and oxidative deterioration. Since rubber used for fenders has low thermal conductivity and low oxygen permeability, thermal and oxidative deterioration is mainly limited to the surface. When rubber is damaged by fire, carbonization proceeds from the surface depending on the degree of damage.

4) Seawater deterioration

Swelling and modulation of rubber that has been exposed to seawater for a long time is called seawater deterioration. However, since the rubber fender is made from a diene rubber, such as natural rubber (NR) or styrene butadiene rubber (SBR), it is stable against seawater (water). Most rubber formulas have long been used for waterproofing and water-resistant applications due to their low swelling with seawater.

5) Chemical deterioration

Natural rubber (NR) and styrene butadiene rubber (SBR) swell when in contact with oils and solvents. This phenomenon is called chemical deterioration. Oils and solvents generally float on the surface of water due to their small specific gravity, but it is unlikely they would come in constant contact with rubber fenders.

6) Fatigue deterioration

Even with small strains or stresses, cracks are generated and develop through repetition. The phenomenon in which the strength characteristics gradually decrease due to creep or stress relaxation is called fatigue deterioration. The fatigue deterioration of a rubber fender changes the reaction force, causing a decrease in the necessary amount of energy absorption.

7) Destruction due to external force

External deterioration that causes rubber to be subjected to breaking strain or force exceeding breaking stress and causes cracks or breaking is referred to as destruction by external force. In the case of rubber fenders, sudden destruction such as cracking and breakage are caused by the abnormal berthing of vessels, excessive deformation by vessels, etc., as well as hooking and rubbing due to projections or irregularities on the hull of vessels. In addition, due to repeated vertical and horizontal movements due to the motion of a vessel during mooring, an uneven portion on the surface of the vessel comes in contact with the surface of the fender, and the rubber portion is repeatedly attacked, and damage to the rubber gradually progresses.

(2) Deterioration factor of accessories

1) Steel member

Corrosion:

Corrosion occurs when metal is altered or consumed from the surface by chemical reactions with water, oxygen, etc. This change in the steel members of rubber fenders is called corrosion deterioration. As shown in Fig. 2.1.2, five corrosive environments are classified according to the installation position of the steel structure. Since rubber fenders are installed in a "splash zone", "tidal zone" and "in the sea" where the corrosive environment is severe, special attention is required for corrosion and deterioration. In general, steel members installed in places with severe corrosive environments need to be plated (galvanized, aluminized) or painted (epoxy resin, etc.) on the surface. In addition, stainless steel may be

adopted as a corrosion-resistant material.

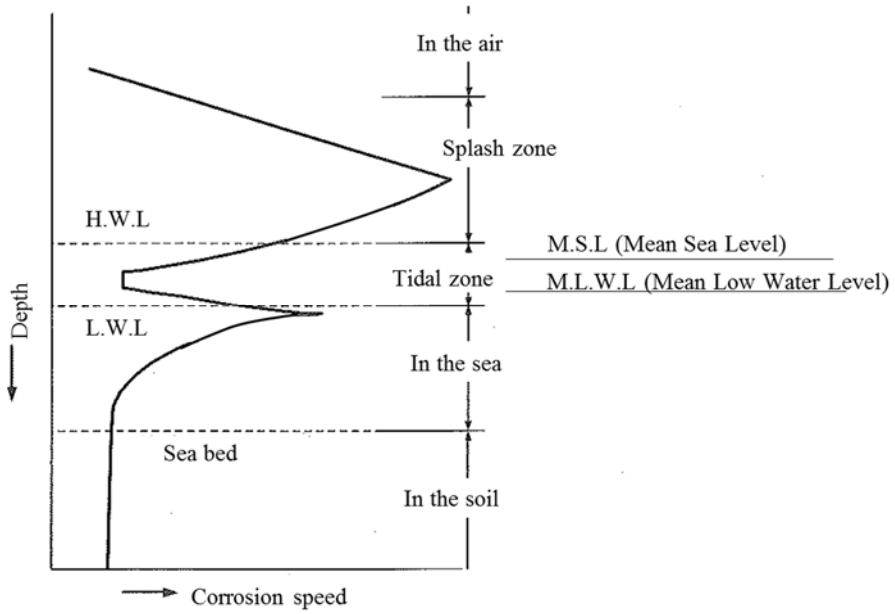


Fig. 2.1.2 Corrosion speed of steel in coastal area[2)]

Deterioration by external force:

When an external force that exceeds the stress assumed in design is applied to steel material, breakage or damage occur, causing deterioration of the fender system. This is called deterioration by external force.

2) Resin pad and others

Ageing deterioration:

A phenomenon in which the function and performance of a member deteriorate over time due to the natural environment and fatigue in use is called ageing deterioration.

Deterioration by external force:

When an external force exceeding the stress assumed in design is applied to a member, breakage or damage occur, causing deterioration. This is called deterioration by external force.

2.1.3 Deterioration modes of rubber fenders

The deterioration modes of rubber fenders, bodies and accessories are as follows.

Rubber body: Drops, tears, permanent deformation, missing rubber, cracks, chipping, separation, wear, ozone cracks, cuts, burns, bolt hole damage

Accessories: loose, bent, missing, cuts, corrosion, abrasion and wear, tears, cracks

(1) Rubber body of fender

The rubber body has different deterioration modes depending on the type of rubber fender. The deterioration modes for each type of rubber fender are shown in Table 2.1.1.

Table 2.1.1 Deterioration modes for rubber fenders

Fender / Deterioration mode	V-type fender	Rubber fender with panel	Pneumatic fender		Cylindrical
			Floating	With panel	
Drops	○	―	―	―	○
Tears	○	○	―	―	○
Permanent deformation	○	○	―	―	―
Missing rubber	○	―	―	―	○
Cracks	○	○	○	○	○
Chipping	○	―	○	―	○
Separation	○	○	○	○	―
Wear	○	―	○	○	○
Ozone cracks	○	○	○	○	○
Cuts	―	―	○	○	―
Burns	○	○	○	○	○
Bolt hole damage	○	○	―	○	―

(2) Fender accessories

Accessories are classified into fixings, supports (including chains), fender panels, resin pads, mooring parts, and others (net, air injection valve, etc.). Each degradation mode is shown in Table 2.1.2.

Table 2.1.2 Deterioration modes of accessories

Parts \ Mode \ Fender		V-type fender	Rubber fender with panel	Pneumatic fender		Cylindrical
				Floating	With panel	
Fixings	Loose	○	○	―	○	―
	Bent	○	○	―	○	―
	Missing	○	○	―	○	―
	Cut	○	○	―	○	―
	Corroded	○	○	―	○	―
Supports	Bent	―	○	―	○	○
	Cut	―	○	―	○	○
	Corroded	―	○	―	○	○
Fender panel	Deformation	―	○	―	○	―
	Corrosion	―	○	―	○	―
Resin pad	Abrasion/Wear	―	○	―	○	―
	Cuts	―	○	―	○	―
	Missing	―	○	―	○	―
	Burns	―	○	―	○	―
Mooring parts	Bent	―	―	○	―	―
	Cut	―	―	○	―	―
	Corroded	―	―	○	―	―
Others (Net, Air inlet, etc.)	Malfunction	―	―	○	○	―
	Corroded	―	―	○	○	―
	Cuts	―	―	○	―	―
	Cracks	―	―	○	―	―
	Wear	―	―	○	―	―

2.1.4 Deterioration modes of other rubber equipment

Other rubber equipment used in ports includes rubber ladders, corner protectors, rubber nets, etc., each of which has the following deterioration modes regarding rubber bodies and accessories.

Rubber body: Drops, tears, permanent deformation, missing rubber, cracks, chipping, separation, wear, ozone cracks, cuts, burns, bolt hole damage

Accessories (fixings): loose, bent, missing, cut, corroded

(1) Rubber bodies of other rubber equipment

Typical deterioration modes of other rubber bodies are shown in Table 2.1.3.

Table 2.1.3 Deterioration modes of rubber bodies of other rubber equipment

Product / Deterioration mode	Rubber ladder	Corner protector	Rubber net
Drops	○	―	―
Tears	○	―	―
Permanent deformation	○	○	―
Missing rubber	○	○	―
Cracks	○	○	―
Chipping	○	○	―
Separation	○	○	―
Wear	○	○	―
Ozone cracks	○	○	―
Cuts	○	―	○
Burns	○	○	○
Bolt hole damage	○	○	○

(2) Accessories (Fixings) of other rubber equipment

Typical deterioration modes of accessories are shown in Table 2.1.4.

Table 2.1.4 Deterioration modes of accessories of other rubber equipment

Product / Deterioration mode	Rubber ladder	Corner protector	Rubber net
Loose	○	○	○
Bent	○	○	○
Missing	○	○	○
Cut	○	○	○
Corroded	○	○	○

2.2 V-type rubber fender

2.2.1 Configuration of V-type rubber fender

V-type rubber fenders are divided into V-type and pivoted V-type according to their shapes. The member is composed of a rubber body and accessories (fixings). The rubber body of a V-type rubber fender comprises a rubber body portion and a fixing portion (fixing flange), and steel plates are embedded in the fixing flange. The names of each part are shown in Fig. 2.2.1 (V-type) and Fig. 2.2.2 (pivoted V-type).

(1) V-type rubber fender

Rubber body

Fixings

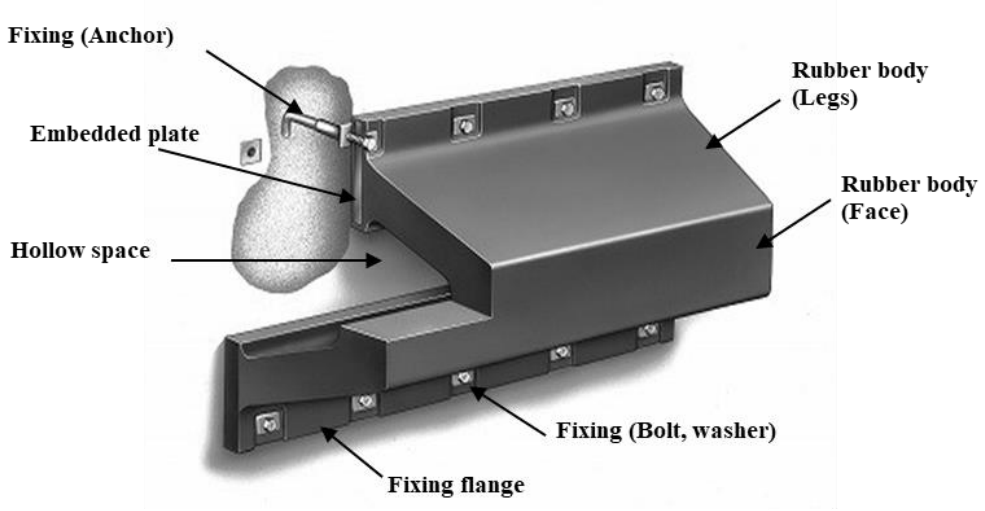


Fig. 2.2.1 Configuration of V-type rubber fender

(2) Pivoted V-type rubber fender (Circle)

Rubber body

Fixings

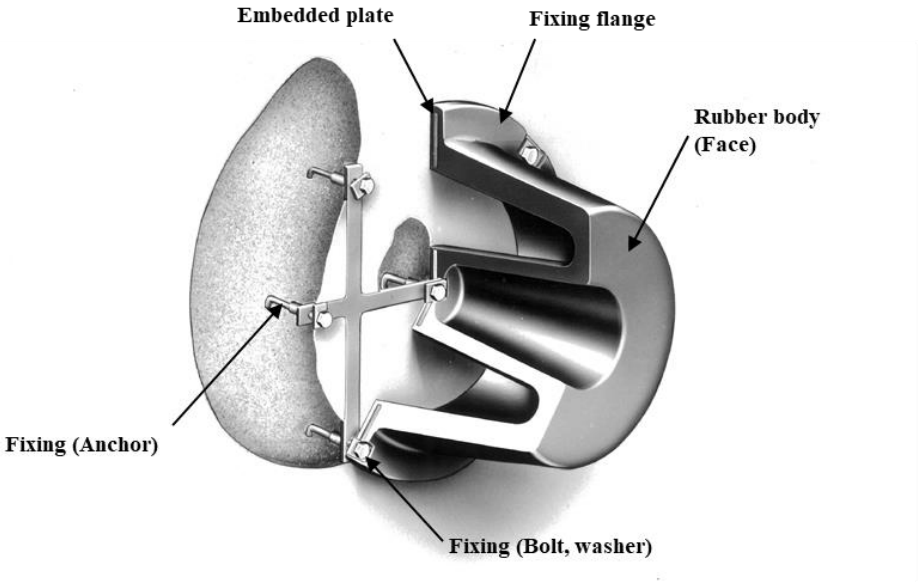


Fig. 2.2.2 Configuration of pivoted V-type rubber fender

2.2.2 Deterioration modes of V-type rubber fender

Deterioration modes regarding V-type rubber fenders are as follows.

Rubber body: Drops, tears, permanent deformation, missing rubber, cracks, chipping, separation, wear, ozone cracks, cuts, burns, bolt hole damage

Accessories (fixings): loose, bent, missing, cut, corroded

(1) Rubber body

1) Drops

"Drops" are the progressive defects of cracking and missing rubber, leaving no rubber present in the face and legs of the rubber body, with the defect eventually reaching hollow space, as shown in Photo 2.2.1

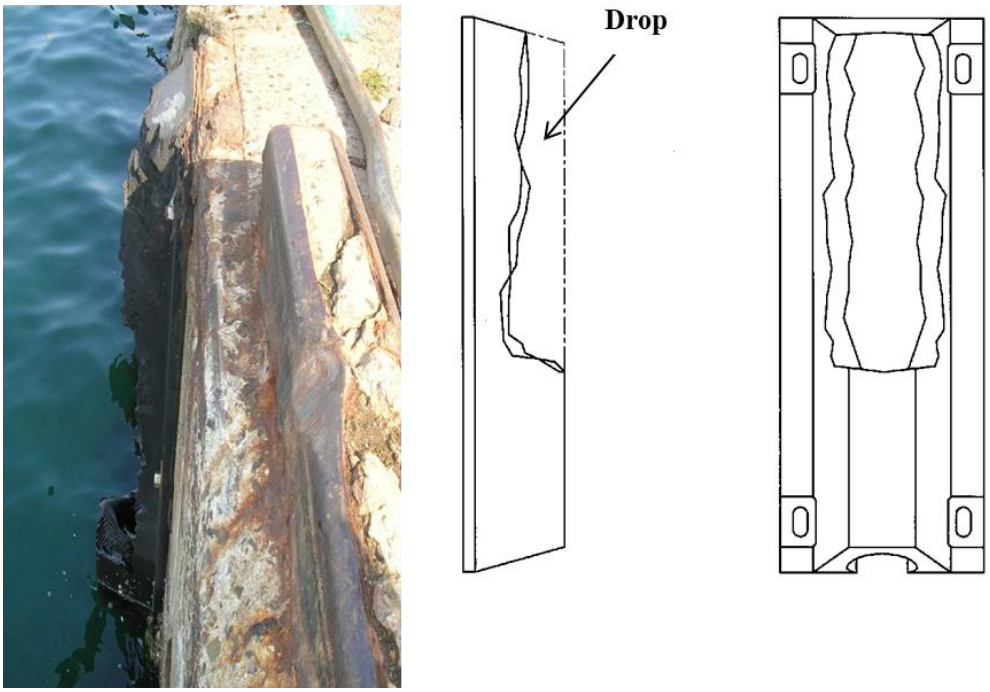


Photo 2.2.1 Drop of a rubber body

2) Tears

As shown in Photo 2.2.2, cracks in the face and legs of the rubber body progress and reach a hollow part called a "Tear".

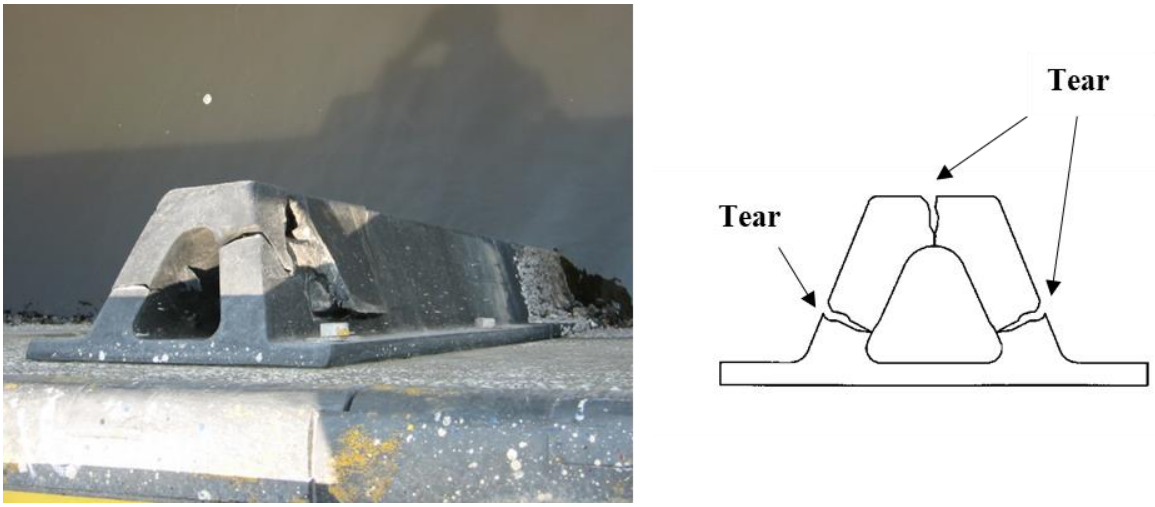


Photo 2.2.2 Tear of a rubber body

3) Permanent deformation

As shown in Photo 2.2.3, a condition in which the face, legs, or fixing flange of a rubber body are deformed and do not return to their original shape is called "Permanent deformation".

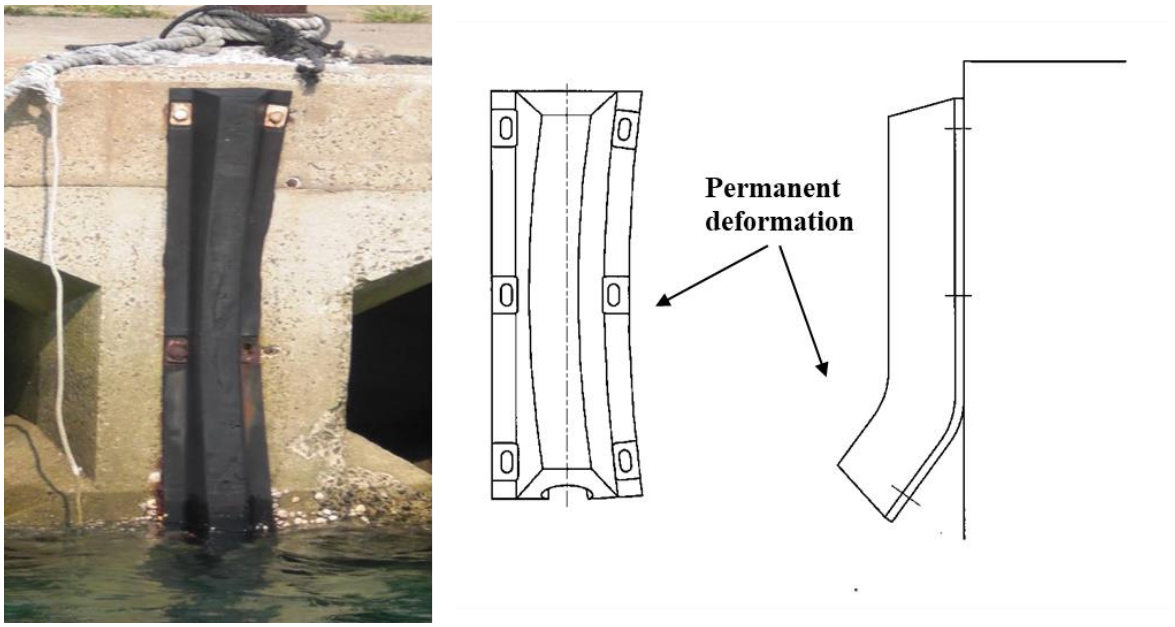


Photo 2.2.3 Permanent deformation of a rubber body

4) Missing rubber

As shown in photo 2.2.4, when chunks of rubber are scraped off at the face of the rubber body, but the defect has not reached the hollow part, This is called "Missing rubber".

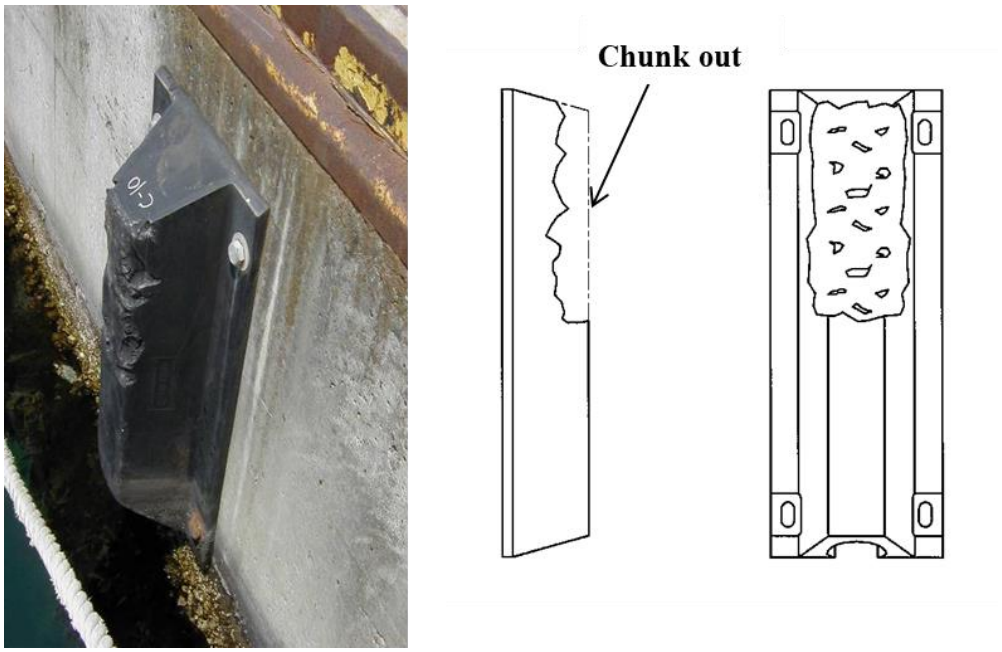


Photo 2.2.4 Missing rubber from rubber body

5) Cracks

As shown in Photo 2.2.5, the rubber surface is partially cut at the face and legs of the rubber body, but the defect does not reach the hollow part; these are called "Cracks".

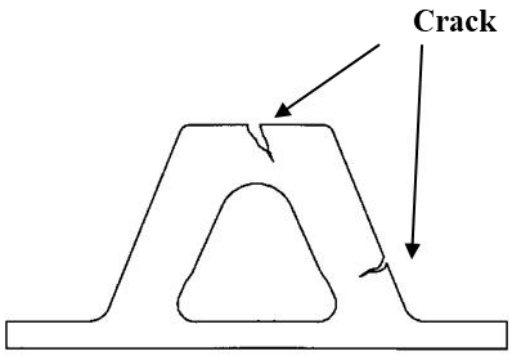


Photo 2.2.5 Cracks in rubber body

6) Chipping

As shown in Photo 2.2.6, the condition where the rubber surface is damaged in a dotted manner on the face of the rubber body is called "Chipping".

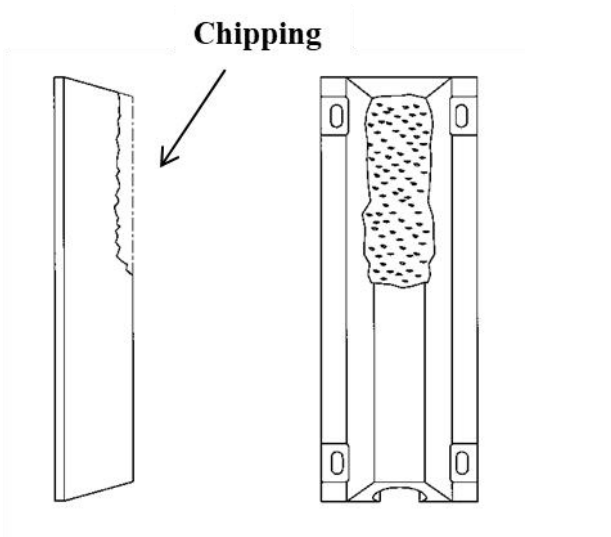


Photo 2.2.6 Chipping of rubber body

7） Separation

As shown in Photo 2.2.7, the condition where rubber parts on surface and side of fixing flange are separated from the embedded steel plate is called "Separation".

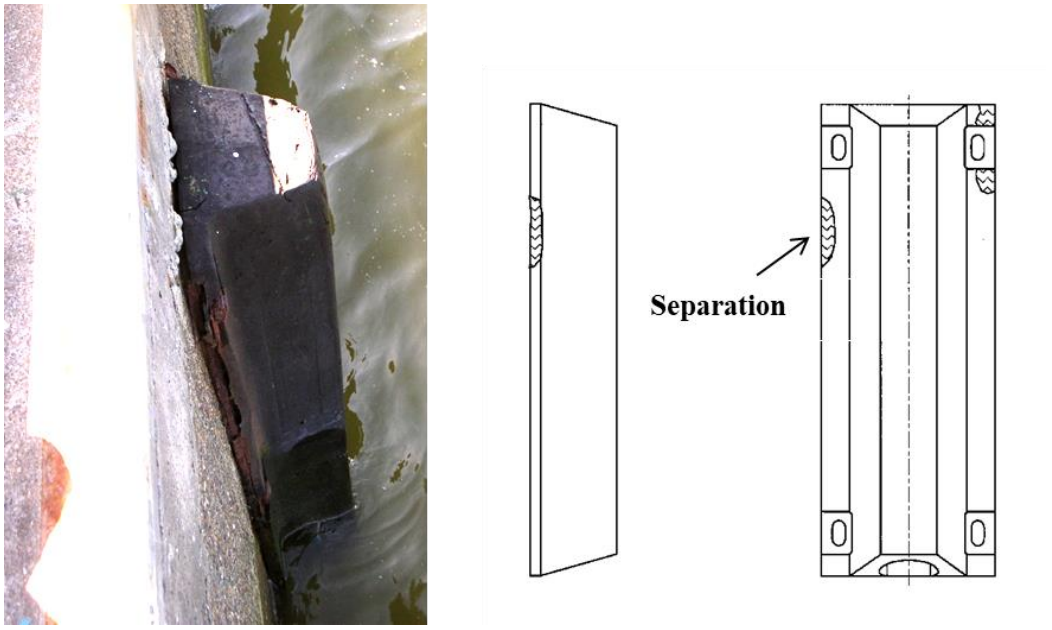


Photo 2.2.7 Separation of rubber body

8) Wear

As shown in Photo 2.2.8, the condition in which corners of face of rubber body are worn away (rounded) is called "Wear".

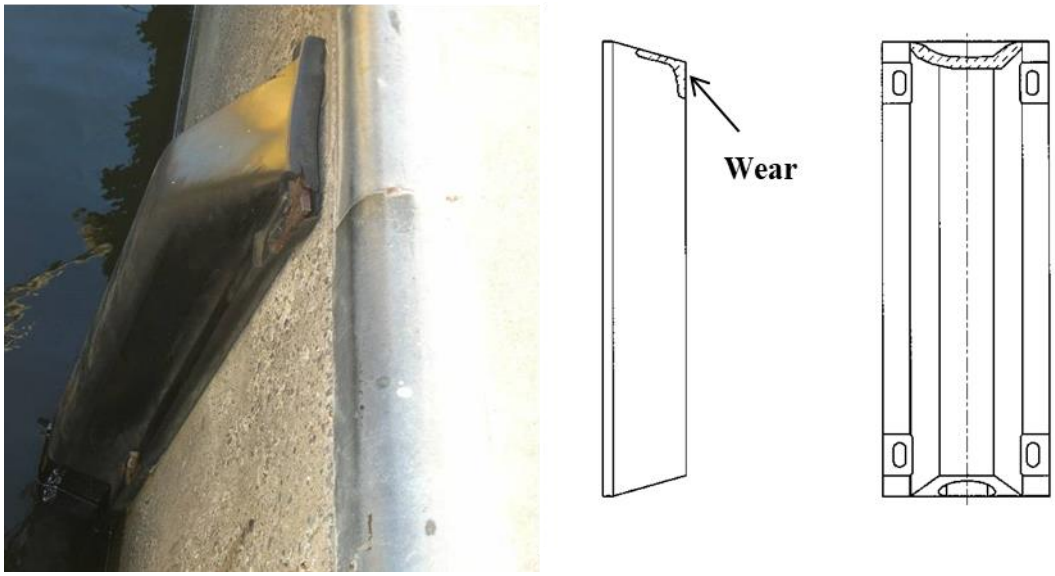


Photo 2.2.8 Wear of rubber body

9) Ozone cracks

As shown in Photo 2.2.9, innumerable small cracks are generated on the surface of the rubber body, legs, hollow space, and fixing flange, which are called "ozone cracks".

Photo 2.2.9 Ozone cracks on a rubber body

10) Burns

As shown in Photo 2.2.10, a condition where the rubber body is damaged by heat, such as fire, and the surface is carbonized is called a "Burn".

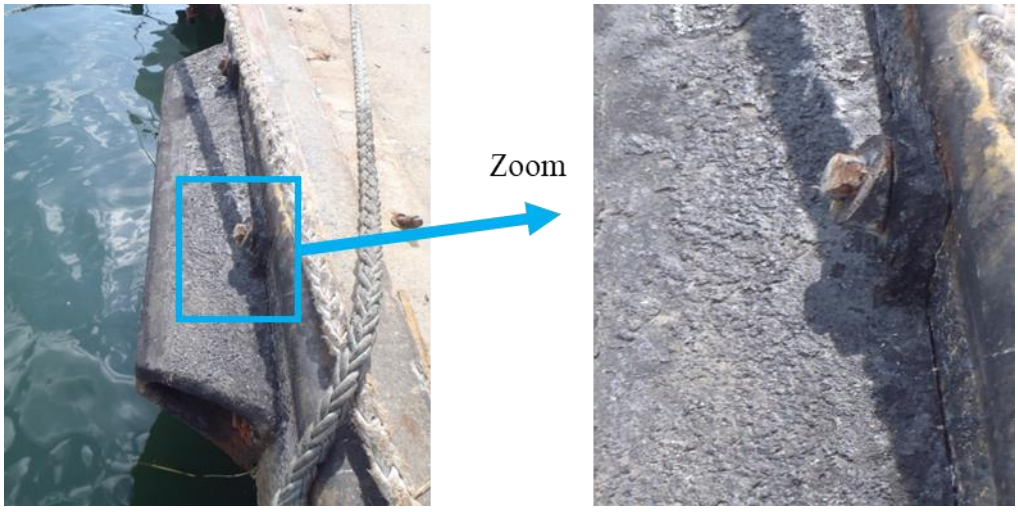


Photo 2.2.10 Burn of rubber body

11) Bolt hole damage

As shown in photo 2.2.11, a condition in which the bolt hole is damaged by external force or corrosion is called "Bolt hole damage".

Photo 2.2.11 Bolt hole damage to a rubber body

(2) Accessories (Fixings)

1) Loose

As shown in photo 2.2.12, the condition where bolt (nut) is loose is called "Loose."

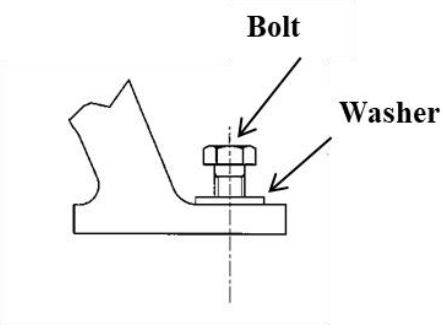


Photo 2.2.12 Loose fixing bolt (Accessories)

Note 1: If a bolt (nut) is used loose, there is a risk of damaging the rubber body (leg) or vessel hull, so retightening is necessary.

Note 2: Since it is possible to prevent the looseness of a bolt (nut) by spot welding the bolt (nut) and washer after tightening, it is recommended to do so.

2) Bend

As shown in photo 2.2.13, a large force is applied to fixing the bolt, and the state in which the bolt is bent is called a "Bend".

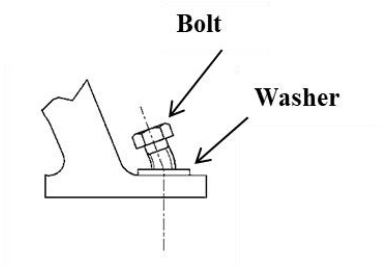


Photo 2.2.13 Bent fixing bolt (Accessories)

3) Missing

As shown in photo 2.2.14, the state of loosening of fixing bolt progresses and it falls off, or bolt itself comes out, and it does not play the role of suppressing the fenders, it is called "Missing".

Photo 2.2.14 Missing fixing bolt (Accessories)

Note 1: The loosening of a fixing bolt is gradually advancing before coming off, and it can be prevented by retightening when loosening is found.

Note 2: If a fender is used without bolts, an excessive load is placed on other remaining bolts, and there is a risk of accelerating failure of the fender system, so an immediate repair is necessary.

Note 3: Care should be taken, as poor concrete strength and poor anchor installation can also lead to "missing" bolts.

4) Cuts

As shown in photo 2.2.15, the broken state of the bolt due to excessive external force applied to the bolt is called a "Cut".

Photo 2.2.15 Cut fixing bolt (Accessories)

Note 1: If a fender is used without bolts, an excessive load is placed on other remaining bolts, and there is a risk of accelerating failure of the fender system, so an immediate repair is necessary.

5) Corrosion

As shown in photo 2.2.16, a state where rusting has occurred and progressed on fixing bolts is called "Corrosion".

Photo 2.2.16 Corrosion of fixing bolt (Accessories)

2.3 Rubber fender with fender panel

2.3.1 Configuration of rubber fender with panel

Rubber fenders with fender panels are fenders that absorb the berthing energy of a vessel by buckling deformation of the rubber body and are divided into longitudinal (rectangular) and circular types according to their shapes. The member is composed of a rubber body and a steel fender panel installed on the front surface of the rubber body and

other accessories (fixing, support and resin pad). The rubber body of the fender with a panel is composed of a rubber body, a fixing flange and a steel plate embedded in a fixing flange.

(1) Rubber fender with panels (Longitudinal)

The configuration of a rubber fender with panels (longitudinal) is shown in Fig. 2.3.1.

1) Rubber body
2) Fender panel
3) Fixing
4) Support
5) Resin pad

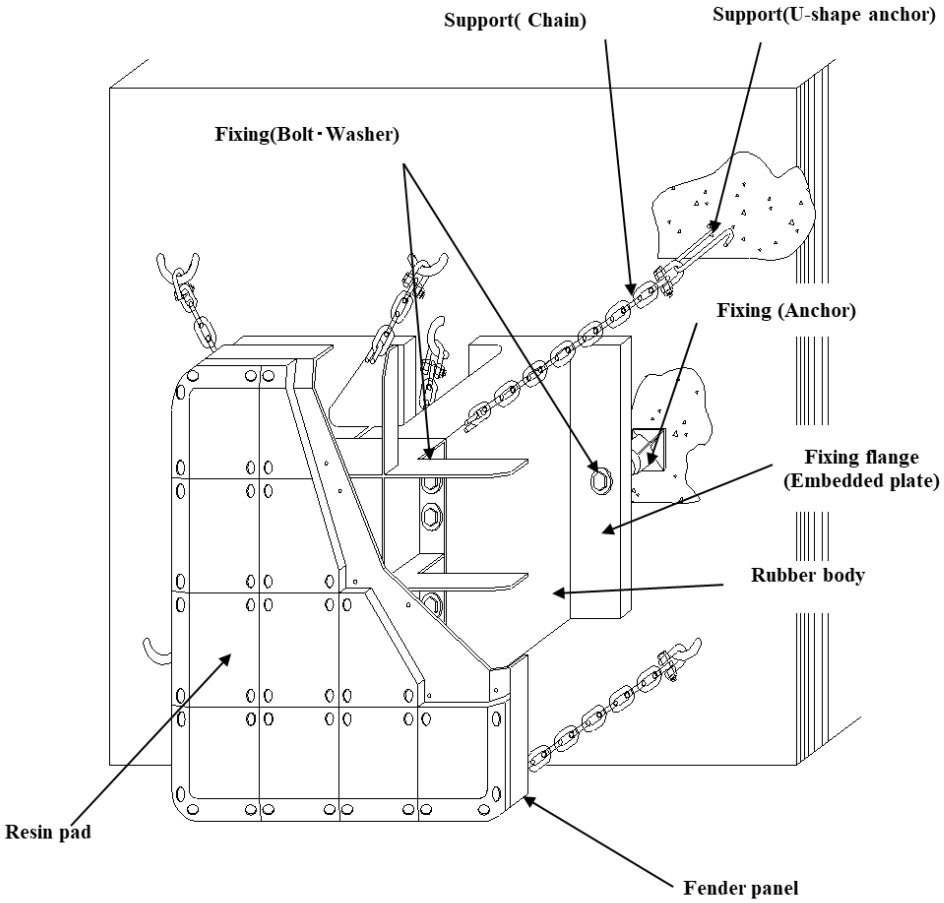


Fig. 2.3.1 Configuration of longitudinal rubber fender with panel

(2) Rubber fender with panels (Circular)

The configuration of a rubber fender with panels (Circular) is shown in Fig. 2.3.2.

1) Rubber body
2) Fender panel
3) Fixing
4) Support
5) Resin pad

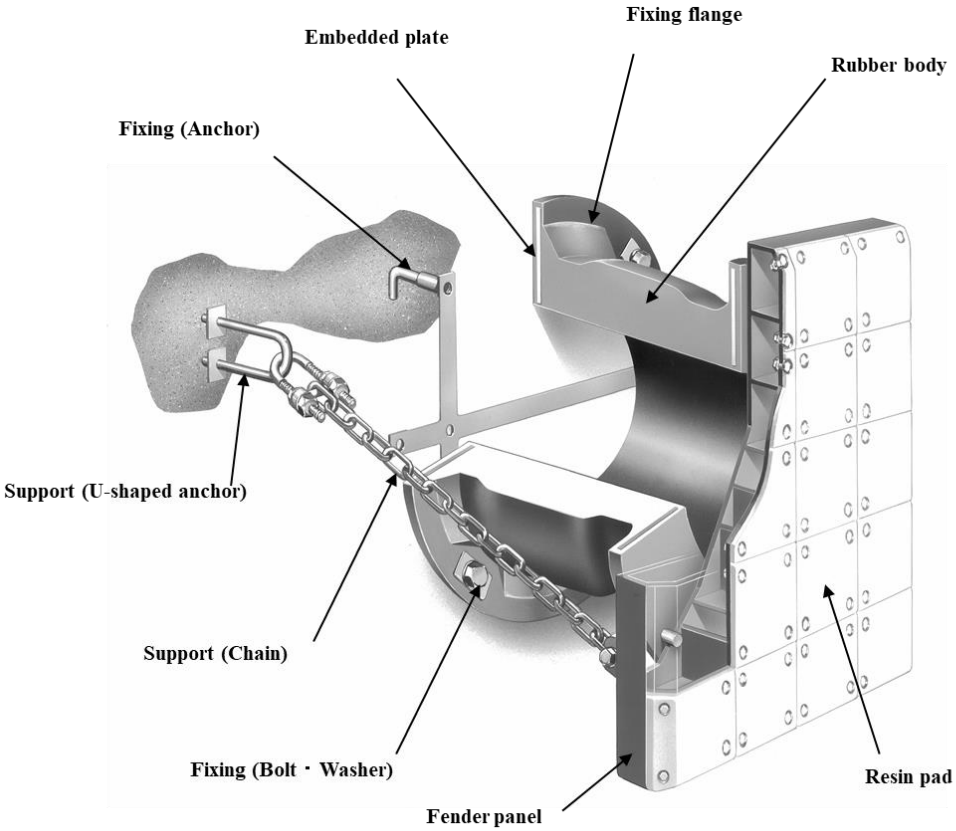


Fig. 2.3.2 Configuration of longitudinal rubber fender with panel

2.3.2 Deterioration modes of rubber fender with panel

The degradation modes of a rubber fender with a panel are as follows.

Rubber body: tears, permanent deformation, cracks, separation, ozone cracks, burns, bolt hole damage,
Panel: deformation, corrosion,
Fixing: loose, bent, missing, cut, corroded
Support: bent, cut, corroded
Resin pad: wear, abrasion, cut, missing, burn

(1) Rubber body

1) Tears

As shown in Photo 2.3.1, a crack occurring in the rubber body that has progressed and reached a hollow part is called a "tear".

Photo 2.3.1 Tear of rubber body

2) Permanent deformation

As shown in Photo 2.3.2, a condition in which the rubber body and fixing flange are deformed and do not return to their original shape is called a "permanent deformation".

Photo 2.3.2 Permanent deformation of a rubber body

3) Cracks

As shown in Photo 2.3.3, a condition where the rubber body is partially cut on the surface but does not reach the hollow part is called a "crack".

Photo 2.3.3 Crack in rubber body

4) Separation

As shown in Photo 2.3.4, a condition where the rubber part of a surface or the side of a fixing flange of a rubber body is peeling off from the embedded steel plate is called a "separation".

Photo 2.3.4 Separation of rubber body

5) Ozone cracks

As shown in Photo 2.3.5, innumerable small cracks on the surface of the rubber body are called "ozone cracks".

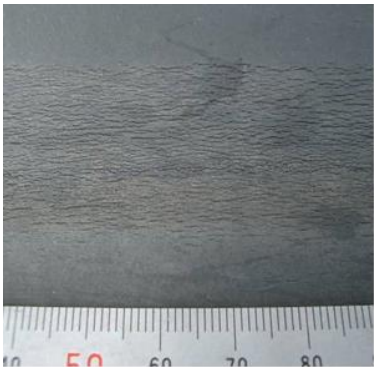


Photo 2.3.5 Ozone cracks on a rubber body

6) Burns

As shown in Photo 2.3.6, a rubber body damaged by heat, such as fire, with a carbonized surface of the rubber body is called a "burn".

Photo 2.3.6 Burn of rubber body

7) Bolt hole damage

Refer to Photo 2.2.11 Bolt hole damage of a rubber body.

(2) Fender panel

1) Deformation

As shown in Photo 2.3.7, the state of plastic deformation of a fender panel or a part of it by the action of an external force is called "deformation".

Photo 2.3.7 Deformation of a fender panel

2) Corrosion

As shown in Photo 2.3.8, a state where rust has occurred and has progressed is called "corrosion".

Photo 2.3.8 Corrosion of a fender panel

(3) Fixings

1) Loose

As shown in Photo 2.3.9, a condition where a bolt or nut is loose is called "loose."

Photo 2.3.9 Loose fixing bolt

2) Bend

As shown in Photo 2.3.10, a condition where a fixing bolt is bent due to an excessive external force is considered a "bent".

Photo 2.3.10 Bent fixing bolt

3) Missing

As shown in Photo 2.3.11, when the loosening of an anchor bolt progresses and falls off, or the anchor itself is pulled out, it is considered "missing".

Photo 2.3.11 Missing fixing bolt

4) Cuts

As shown in Photo 2.3.12, when a fixing bolt is subjected to excessive external force, the broken state is called a "cut".

Photo 2.3.12 Cut fixing bolt

5) Corrosion

As shown in Photo 2.3.13, the occurrence and progression of rust is called "corroded".

Photo 2.3.13 Corrosion of fixing bolt

(4) Supports

1) Bend

As shown in Photo 2.3.14, an excessive external force is applied to supporting parts, and the state in which the part is bent is referred to as "bent".

Photo 2.3.14 Bent support (Adjustable U-shape shackle)

2) Cut

As shown in photo 2.3.15, the support part is subjected to excessive external force and broken. This state is called "cutting".

Photo 2.3.15 Cut of support (Chain shackle)

3) Corrosion

As shown in photo 2.3.16, the state where rust has occurred and has progressed is called "corroded".

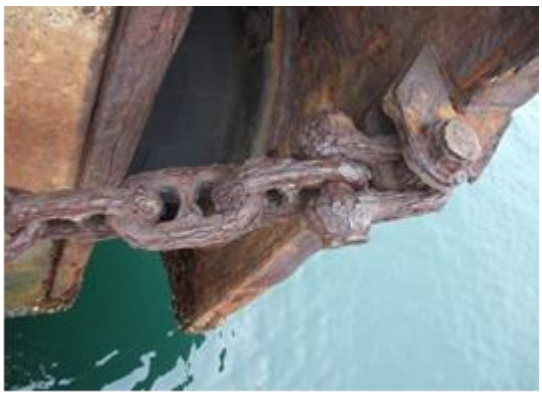


Photo 2.3.16 Corrosion of support (Chain)

(5) Resin pad

1) Abrasion/Wear

As shown in Photo 2.3.17, a condition where abrasion has occurred on the surface of the resin pad due to the contact of the vessel is called “abrasion/wear”.

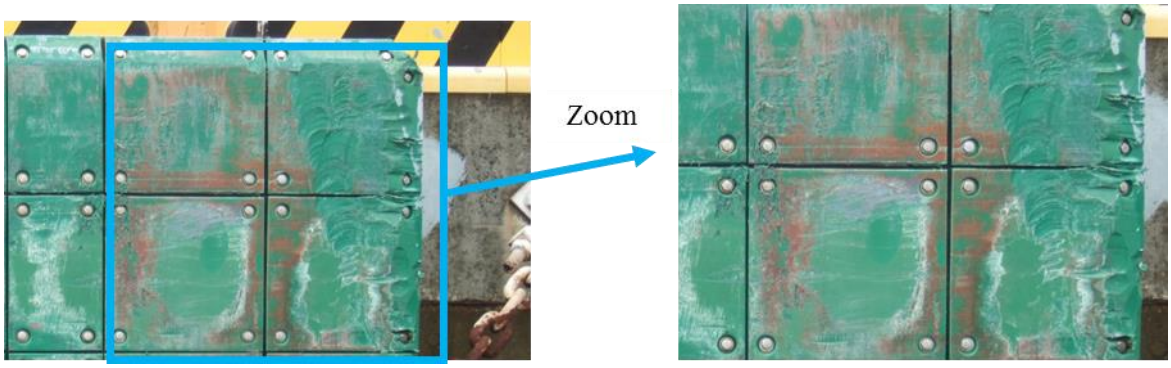


Photo 2.3.17 Abrasion/wear of resin pad

2) Cut

As shown in Photo 2.3.18, a state where a crack has occurred in some resin pads due to the attack of a sharp load is called a "cut".

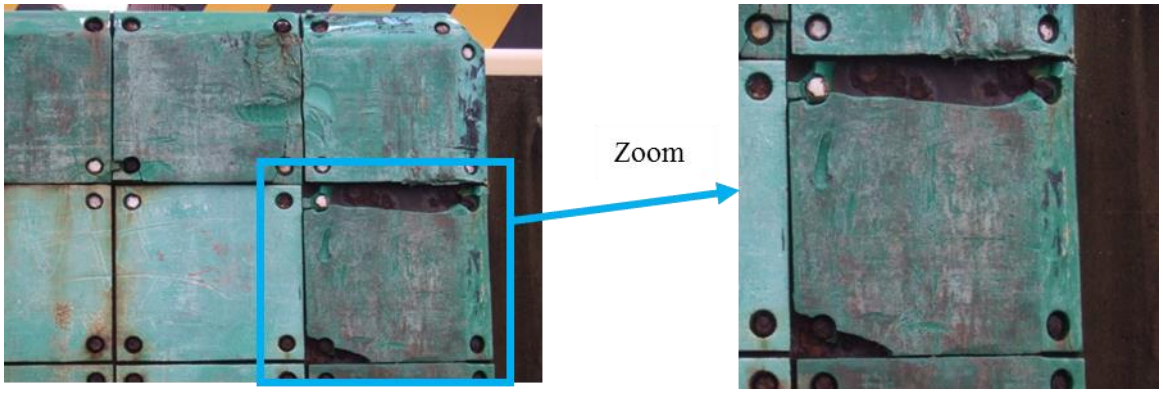


Photo 2.3.18 Cut of resin pad

3) Missing

As shown in Photo 2.3.19, a state in which a part or all of resin pads fall off due to external load is called "missing”.

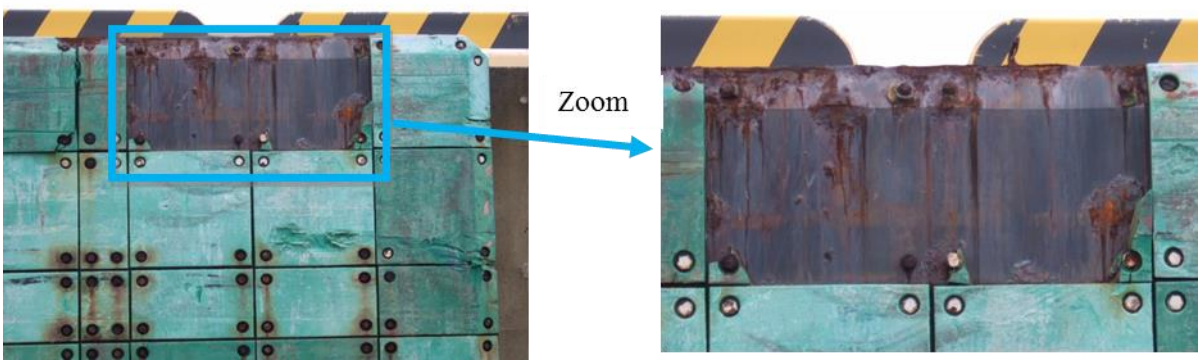


Photo 2.3.19 Missing resin pad

4) Burn

As shown in Photo 2.3.20, a condition where the resin pad is melted or burned off by heat, such as fire, is called a "burn".

Photo 2.3.20 Burned resin pad

2.4 Pneumatic fender

2.4.1 Configuration of pneumatic fender

Pneumatic fenders absorb the energy of a berthing vessel using the elasticity of air filled in a fabric-reinforced rubber bag; there are two types: a floating pneumatic fender and a fixed pneumatic fender with a panel. The member is comprised of a rubber body (bag) and accessories. The rubber body of a floating pneumatic fender is only a rubber bag, but the fixed pneumatic fender with fender panel consists of a rubber bag and a fixing part (fixing flange), and steel plates are embedded in the flange. The rubber body of the pneumatic fender is composed of an outer rubber layer, a reinforcing layer and an inner rubber layer.

(1) Floating-type pneumatic fender

A floating pneumatic fender is composed of a rubber body and accessories (air inlet valve, body attachment, net, mooring attachment). The names of each part are shown in Fig. 2.4.1.

1) Rubber body
2) Air inlet valve
3) Body attachment (base, cover plate, hanging parts)
4) Net
5) Mooring attachment

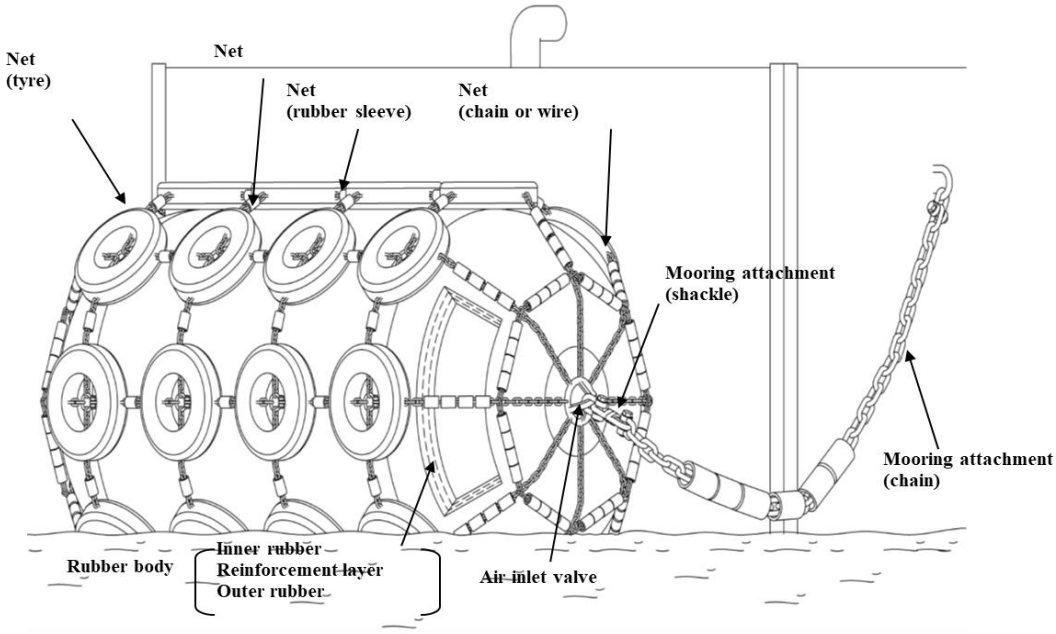


Fig. 2.4.1 Configuration of floating pneumatic fender

(2) Fixed-type pneumatic fender with panel

A fixed-type pneumatic fender with a panel is composed of a rubber body and accessories (air inlet valve, body attachment, fender panel, fixing, support, resin pad). The names of each part are shown in Fig. 2.4.2.

1) Rubber body
2) Air inlet valve
3) Body attachment (valve protector)
4) Fender panel, fixings, supports, resin pad

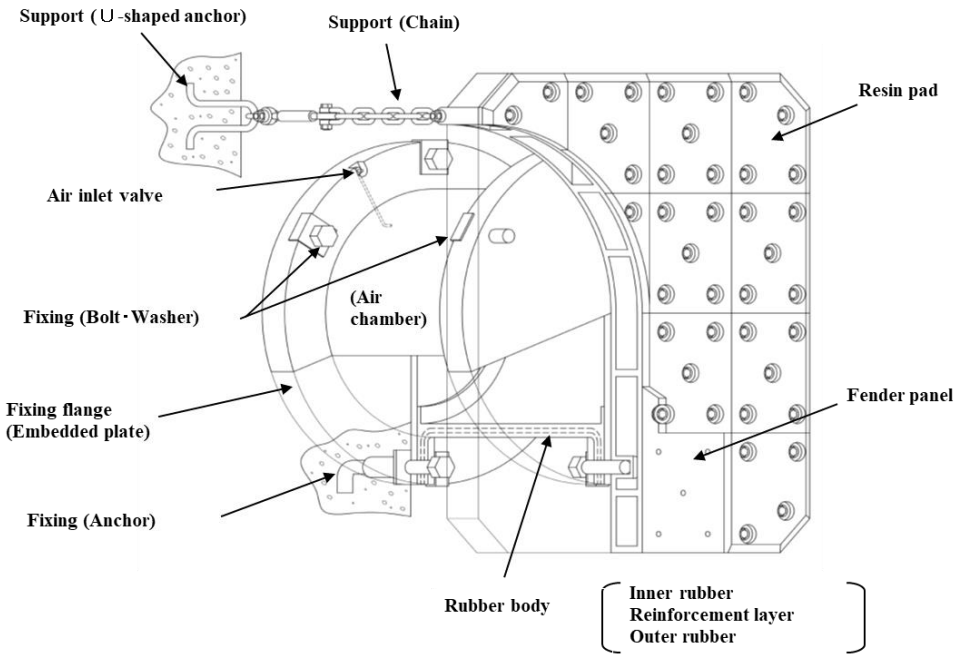


Fig. 2.4.2 Configuration of fixed-type pneumatic fender

2.4.2 Deterioration modes of pneumatic fender

The deterioration modes of pneumatic fenders are as follows.

Rubber body: cracks, chipping, separation, wear, ozone cracks, tears, burns, bolt hole damage

Air inlet valve: damage, corrosion

Body attachment: malfunction, corrosion

Net: corrosion, cuts, cracking, wear, burns

Mooring attachment: fender panel, support and resin pad: corrosion, etc.

(1) Rubber body

1) Cracks, chipping

As shown in Photo 2.4.1, the outer rubber layer and part of the reinforcing layer are partially cut, but the inside of the bag is not pierced, which is called "cracking". In addition, the state where the rubber surface is finely damaged is called "chipping".

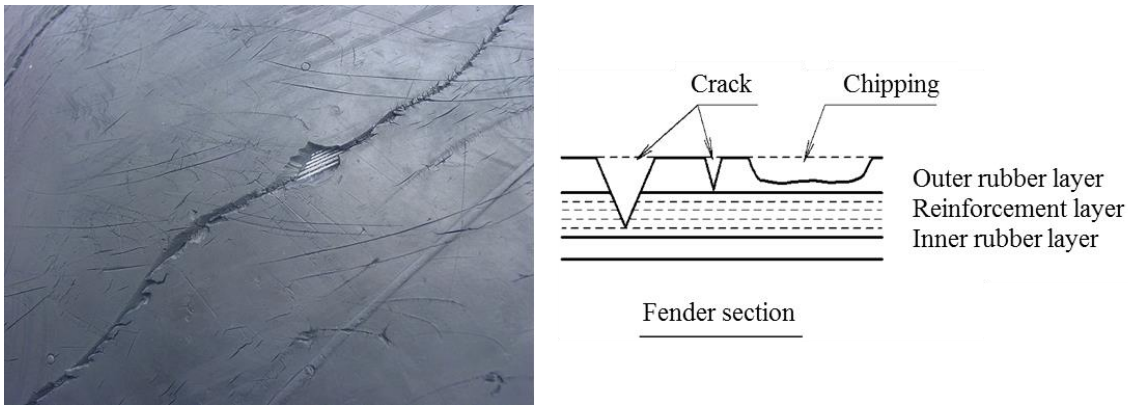


Photo 2.4.1 Cracking and chipping of rubber body

Note) In the case of the crack in this photo, a reinforcement layer is exposed. Perform occasional check and diagnosis as soon as possible because of the risk of decreased pressure resistance.

2) Separation

As shown in Photo 2.4.2, the rubber covering the embedded steel plate to which an air inlet valve is attached is separated, or as shown in Photo 2.4.3, the state in which a part is separated is called "separation".

Photo 2.4.2 Separation of rubber body (Embedded plate)

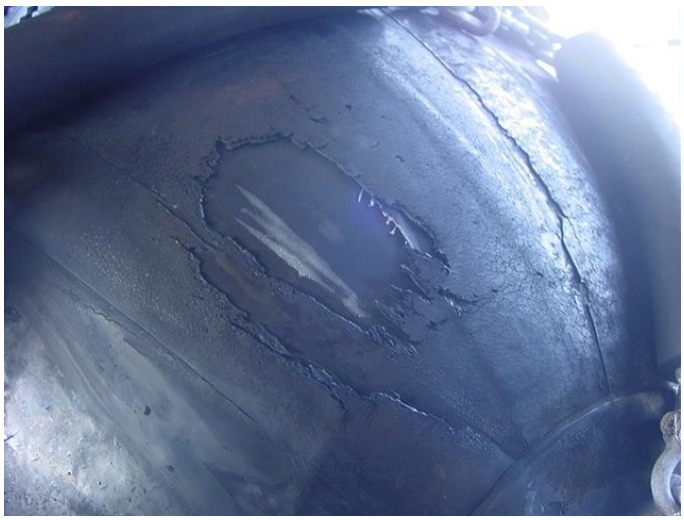


Photo 2.4.3 Separation of rubber body (Outer layer)

Note) In the case of separation in this example, the reinforcing layer is exposed. Perform occasional check and diagnosis as soon as possible because of the risk of a drop in pressure resistance.

3) Wear

As shown in Photo 2.4.4, the condition in which the outer rubber layer is rubbed and the reinforcing layer becomes visible, or in which the reinforcing layer is also worn, is referred to as "wear".

Photo 2.4.4 Wear of rubber body

Note) In this example, since multiple reinforcing layers are worn, the required pressure resistance may be significantly reduced. Stop using immediately and carry out occasional check and diagnosis.

4) Ozone cracks

As shown in Photo 2.4.5, an infinite number of small cracks are generated on the surface of the outer rubber layer are referred to as "ozone cracks".

Photo 2.4.5 Ozone cracks on rubber body

5) Tears

As shown in Photo 2.4.6, the outer rubber layer, reinforcing layer and inner rubber layer are cut, and the condition in which injury reaches the inside of the rubber bag is called a "tear".

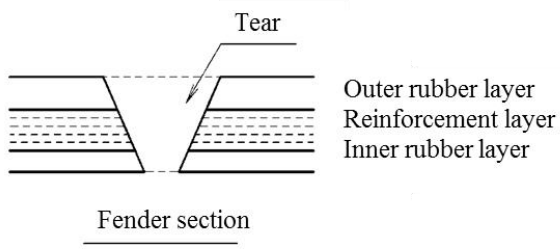


Photo 2.4.6 Tear of rubber body

6) Burn

The situation of burns on the surface, in the case of fire, is similar to the case of Photo 2.3.6 Burn of rubber body.

7) Bolt hole damage (Fixed type)

The degradation form of bolt hole damage conforms to Photo 2.2.11 Bolt hole damage of rubber body.

(2) Air inlet valve

1) Malfunction

As shown in Photo 2.4.7, a state in which an abnormality such as deformation, screw failure or air leak has occurred is called a "malfunction".

Photo 2.4.7 Malfunction of air inlet valve

2) Corrosion

As shown in Photo 2.4.8, the state where rust has occurred and has progressed is called "corroded".

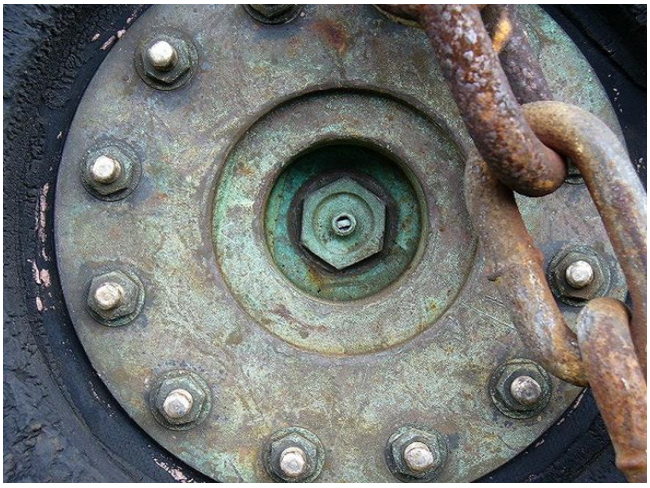


Photo 2.4.8 Corrosion of air inlet valve

(3) Body attachment

As shown in Fig. 2.4.3, the main body attachment includes an air valve, flange plate and hanging metal.

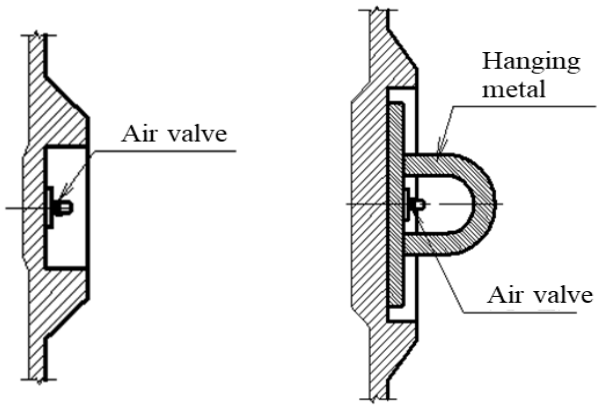


Fig. 2.4.3 Body attachment (floating type)

1) Malfunction

As shown in Photo 2.4.9, a state in which an abnormality such as deformation, cutting, or screw failure has occurred is called a "malfunction".

Photo 2.4.9 Malfunction of body attachment

2) Corrosion

As shown in Photo 2.4.10, the state where rust has occurred and has progressed is called "corroded".

Photo 2.4.10 Corrosion of body attachment

(4) Net (Floating type)

The net is a protective member that covers the main rubber body and is used to secure fenders safely. The net is composed of net members such as chains, wires, ropes and shackles, protective tyres (used tyres) and rubber sleeves.

1) Corrosion

As shown in Photo 2.4.11, the state where rust has occurred and has progressed is called "corroded".

Photo 2.4.11 Corrosion of net

2) Cuts

As shown in Photo 2.4.12, a net that is broken due to excessive external force applied to the net is considered "cut". This also includes a condition where a shackle has fallen off and part of net has come off.

Photo 2.4.12 Cut net

3) Tears

A condition where the tyre and rubber sleeve are broken is called a "tear", as shown in Photo 2.4.13.

Photo 2.4.13 Torn net

4) Wear

As shown in Photo 2.4.14, a condition where the tyre and rubber sleeve are worn away, the fibre layer is exposed (in the case of a tyre) or extends to the hollow part is called "wear".

Photo 2.4.14 Wear of net

5) Burns

A condition where tyres and rubber sleeves are damaged by heat, such as fire, and the surface is carbonized is considered a "burn".

(5) Mooring attachment

The deterioration modes (bent, cut, corroded) of the mooring attachment (in floating types) shall be in accordance with 2.3.2 Deterioration modes of rubber fender with panels (3) and (4). In addition, the degradation modes of the fender panel, fixings, supports, and resin pad (in fixed types with a fender panel) conform to 2.3.2 Deterioration modes of rubber fender with panels (2) to (5).

2.5 Cylindrical fender

2.5.1 Configuration of cylindrical fender

A cylindrical rubber fender is comprised of a cylindrical rubber body and accessories for installation on the quay. The names of each part for the rubber body and supports (chain, steel bar, U-shape anchor) are shown in Fig. 2.5.1.

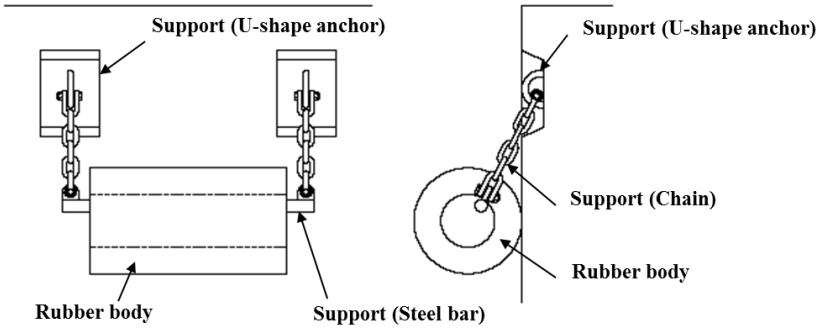


Fig. 2.5.1 Configuration of cylindrical rubber fender

2.5.2 Deterioration modes of cylindrical fender

The deterioration modes of cylindrical rubber fenders include the following.

Rubber body: drops, cracks, missing rubber, tears, chipping, wear, ozone cracks, burns

Supports: bent, cut, corroded

(1) Rubber body

1) Cracks

As shown in Photo 2.5.1, a condition from which a scratch from the outside of the rubber body advances and reaches the hollow space is called a "crack".

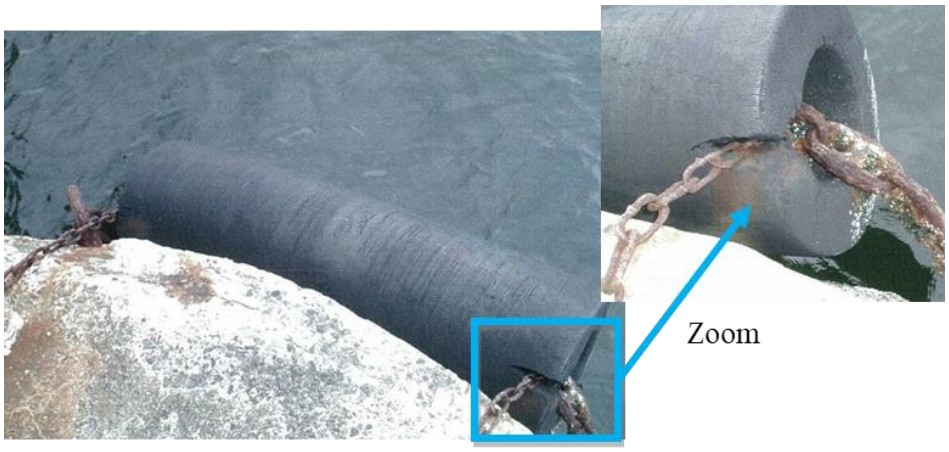


Photo 2.5.1 Crack of rubber body

2) Missing rubber

As shown in Photo 2.5.2, when the rubber is scraped off from outside of the rubber body but has not reached the hollow space, this is considered "missing rubber".

Photo 2.5.2 Missing rubber from rubber body

3) Ozone cracks

As shown in Photo 2.5.3, when numerous small cracks are generated on the surface of the rubber body, these are considered "ozone cracks".

Photo 2.5.3 Ozone cracks in rubber body

4) Drops, tears, chipping, wear and burns

These deterioration modes are based on 2.2.2 Deterioration modes of V-type rubber fenders (1).

(2) Supports

1) Corrosion

As shown in Photo 2.5.4, the state where rust has occurred and has progressed is called "corroded".

Photo 2.5.4 Corrosion of support

2) Bends, cuts

These deterioration modes are based on 2.3.2 The degradation modes of rubber fenders with panels (4).

2.6 Other rubber equipment

2.6.1 Configuration of other rubber equipment

Rubber ladders, corner protectors and rubber nets consist of respective rubber bodies and accessories. The configurations of these items are shown below.

(1) Rubber ladders

A rubber ladder is a safety item for fall prevention that is composed of a rubber body and accessories (Fixings). The names of each part are shown in Fig. 2.6.1.

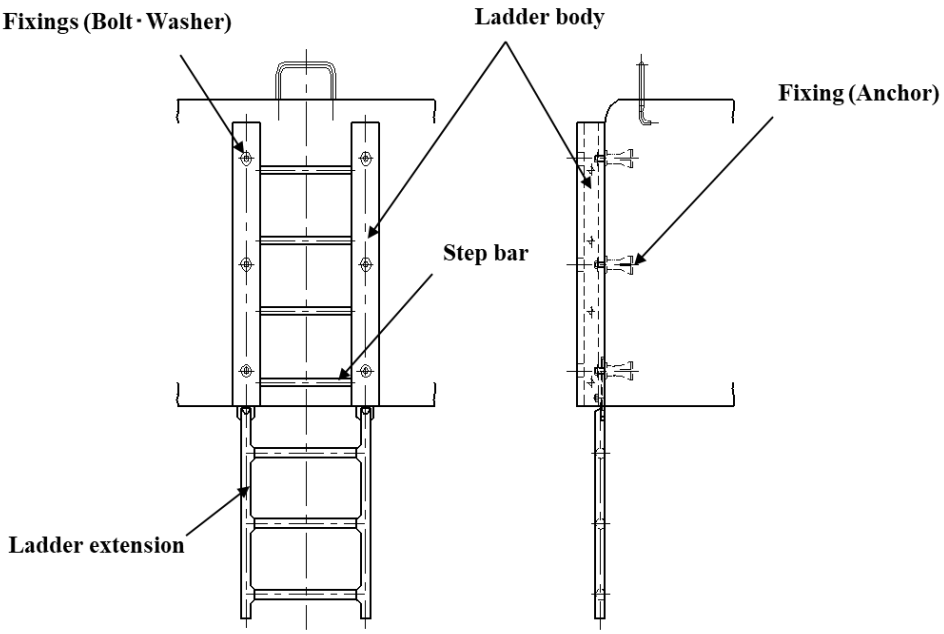


Fig. 2.6.1 Configuration of rubber ladder

(2) Corner protectors

A corner protector is a member that protects the quay top end corner. A corner protector consists of a rubber body and accessories (fixings). The names of each part are shown in Fig. 2.6.2.

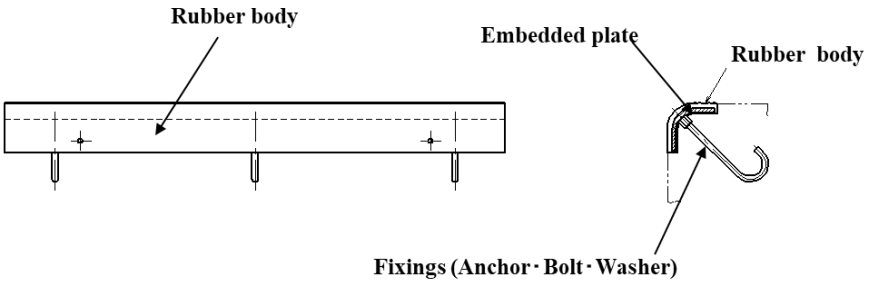


Fig. 2.6.2 Configuration of corner protector

(3) Rubber nets

A rubber net is a member that prevents vessels, driftwood and people from getting into the opening in front of quay. A rubber net consists of a rubber body and accessories (Fixings). The names of each part are shown in Fig. 2.6.3.

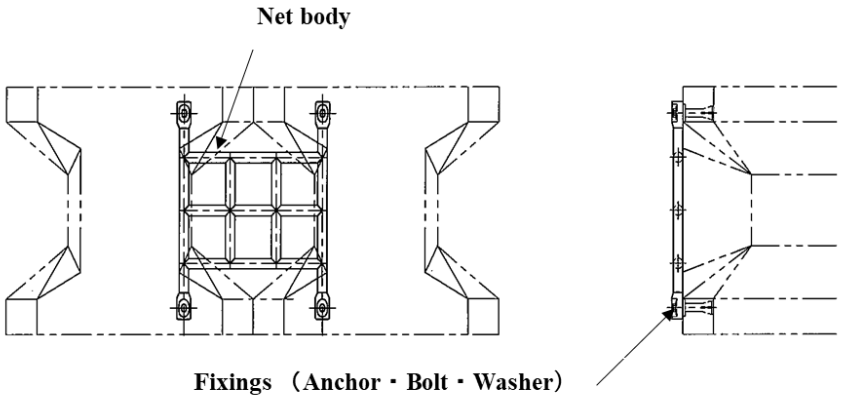


Fig. 2.6.3 Configuration of rubber net

2.6.2 Deterioration modes of other rubber equipment

The deterioration modes of other rubber equipment include the following.

Rubber body: drops, cracks, permanent deformation, missing rubber, cuts, chipping, separation, wear, burns, bolt hole damage, ozone cracks and tears.

Fixings: loose, bent, missing, cut and corroded.

(1) Rubber body

1) Rubber ladder

a. Drops

As shown in Photo 2.6.1, the progress of cracking and breakage in which there is no rubber present in the rubber body and the absence reaches the hollow space is called a "drop".

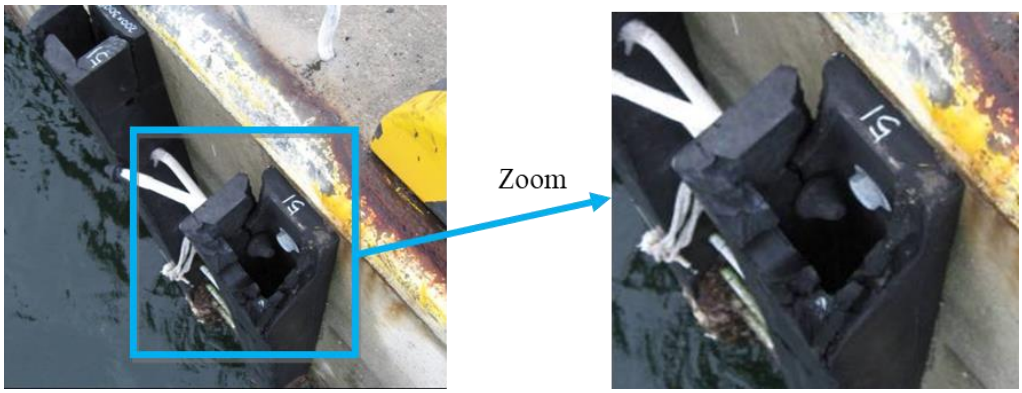


Photo 2.6.1 Drop of rubber body

b. Tears

As shown in Photo 2.6.2, a crack occurring in the rubber body that has progressed and reached the hollow space is called a “tear”.

Photo 2.6.2 Tear of rubber body

c. Permanent deformation

As shown in Photo 2.6.3, a condition in which the rubber body and fixing flange are deformed and do not return to their original shape is called a "permanent deformation".

Photo 2.6.3 Permanent deformation of a rubber body

d. Missing rubber

As shown in Photo 2.6.4, although rubber is scraped off at the rubber body, the state where it does not reach the hollow space is called “missing rubber”.

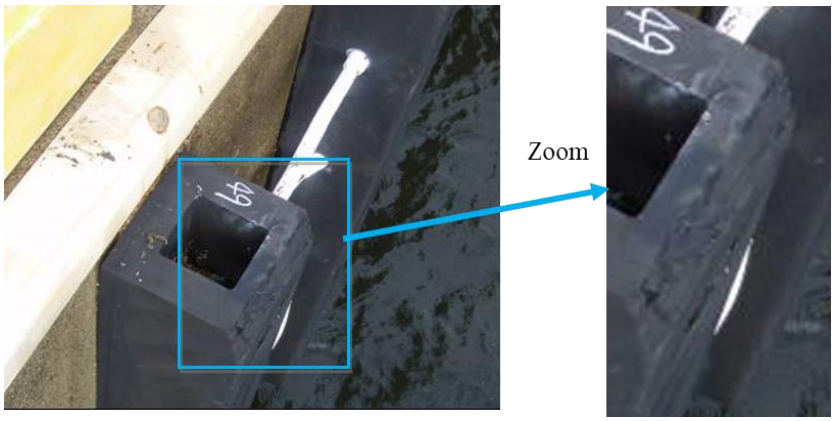


Photo 2.6.4 Missing rubber from rubber body

e. Cuts

As shown in Photo 2.6.5, a condition where the ladder is exposed to excessive external force, etc., and the step portion of the ladder is peeled off is called a "cut". This also includes the situation where a portion of the steps is out.

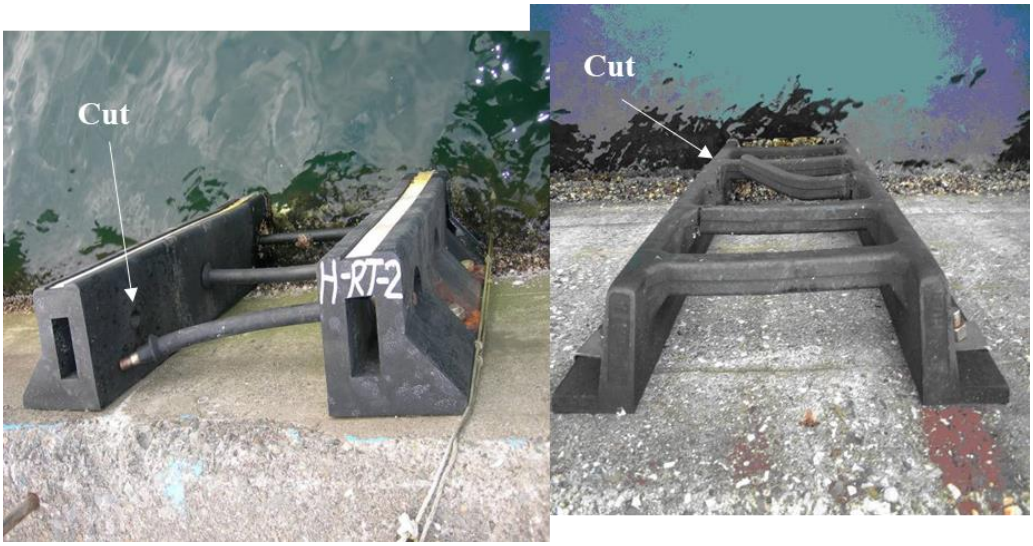


Photo 2.6.5 Cut of rubber body

f. Tears, chipping, separation, wear, ozone cracks, burns and bolt hole damage are similar to 2.2.2 Deterioration modes of V-type rubber fenders (1) Deterioration modes.

2) Corner protectors

Permanent deformation, missing rubber, tears, chipping, separation, wear, ozone cracks, burns and bolt hole damage are similar to 2.2.2 Deterioration modes of V-type rubber fenders (1) Deterioration modes.

3) Nets

a. Cuts

As shown in Photo 2.6.6, a condition where an excessive external force is applied to rubber net and a part of the body is peeled is called a "cut".

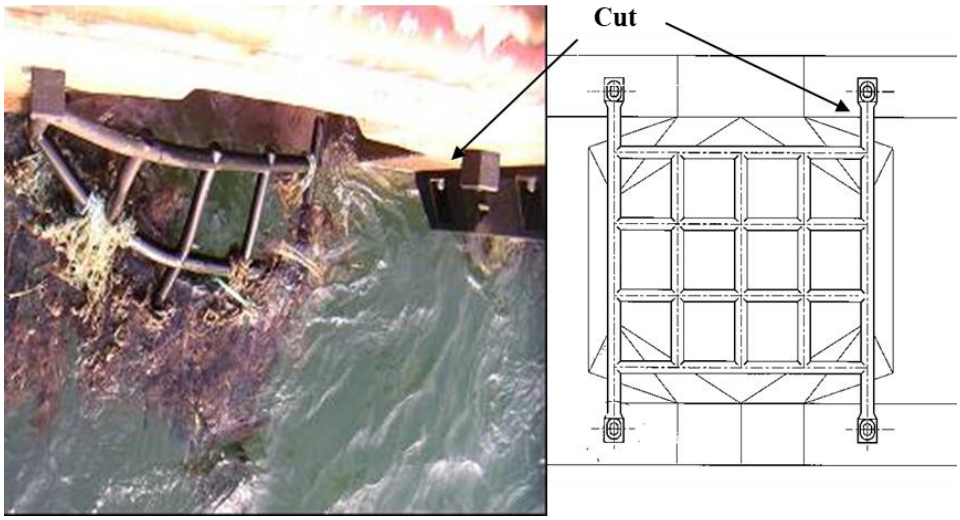


Photo 2.6.6 Cut of rubber ladder

(2) Fixings

The deterioration modes of rubber ladders are similar to 2.2.2 Deterioration modes of V-type rubber fenders (2) Fixings.

〔References〕

1) Nakauchi, H.: Deterioration of rubber composites, Journal of The Society of Rubber Industry, Japan Vol. 64, No. 9, 1991 (Japanese)

2) Coastal Development Institute of Technology (CDIT): Manual on Corrosion Prevention and Repair for Ports and Harbor Steel Structure, No. 35, 2009 (Japanese)

3) Terauchi, K., T. Koizumi, S. Yamamoto, K. Hosokawa: Deterioration Actual State and the Function Evaluation of the Rubber Fender, Technical Note of the Port and Harbour Research Institute, Ministry of Transport, Japan, No. 878, 1997 (Japanese)

4) Association for Innovative Technology on Fishing Ports and Grounds: Fender Replacement Criteria for Fishing Ports (Draft) (Functional evaluation document), 2007 (Japanese)

Chapter 3
Check diagnosis and functional evaluation of rubber fender

3.1 General

3.1.1 Summary

To check and diagnose rubber fenders, the initial check and diagnosis, daily check, periodic check and diagnosis, and occasional check and diagnosis shall be carried out. Based on the results, a functional evaluation shall be performed using the following methods.

Daily check:

The deterioration rank is determined based on the condition of parts and components of both the rubber body and accessories.

Initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis:

For the rubber body, the deterioration score is judged on the basis of measurement of the damaged part. When re-installing the removed rubber fender, consider the functional evaluation according to the condition of bolt hole damage. For accessories, the deterioration rank is determined based on the condition of the parts and members.

(1) Daily checks

The purpose of a daily check is to assess the presence or absence of deterioration in fenders through daily inspections (1.4, Chapter 1), but in this guideline, the deterioration rank is determined in four stages—a, b, c and d—by visual judgement as in the CDIT maintenance manual. The criteria for determining deterioration rank are shown in Tables 3.1.1–3.1.5 for each fender type. If the deterioration is ranked a, an occasional check and diagnosis must be conducted. Additionally, if the deterioration rank is c, plans shall be made for checks and diagnoses. Note that there is nothing that falls under deterioration rank b in the CDIT maintenance manual.

1) V-type rubber fenders

Table 3.1.1 Deterioration rank and mode of daily checks (V-type rubber fenders)

Rank	Deterioration mode of parts
a	Rubber body: drops, cracks, permanent deformation, burns Accessories (fixings): loose, bent, missing or cut
b	------
c	Rubber body: missing rubber, cracks, chipping, separation, wear, ozone cracks Accessories (fixings): corroded
d	No deterioration

2) Rubber fenders with panel

Table 3.1.2 Deterioration rank and mode of daily checks (Rubber fenders with panel)

Rank	Deterioration mode of parts
a	Rubber body: tears, permanent deformation, cracks (large), burns Fixings: loose, bent, missing, cut Supports: bent, cut Fender panel: deformation Resin pad: cut, missing, burns
b	-------
c	Rubber body: tears (small), separation, ozone cracks Fixings: corroded Supports: corroded Fender panel: corroded Resin pad: abrasion & wear
d	No deterioration

3) Pneumatic fenders

Table 3.1.3 Deterioration rank and mode of daily checks (Pneumatic fenders)

Rank	Deterioration mode of parts
a	Rubber body: cuts, wear (to fabric layer), burn, decreased air pressure Fixings: loose, bent, missing, cut Attachments: bent, cut Fender panel: deformation Resin pad: cut, missing, burns
b	-------
c	Rubber body: tears (small), separation, ozone crack airtightness malfunction Fixings: corroded Attachments: corroded
d	No deterioration

4) Cylindrical fenders

Table 3.1.4 Deterioration rank and mode of daily checks (Cylindrical fenders)

Rank	Deterioration mode of parts
a	Rubber body: drops, tears, burns Supports: bent, cut
b	-------
c	Rubber body: missing rubber, cracks, chipping, wear, ozone cracks Supports: corroded
d	No deterioration

5) Other rubber equipment

Table 3.1.5 Deterioration rank and mode of daily checks (Other rubber equipment)

Rank	Deterioration mode of parts
a	Rubber body: drops, tear, permanent deformation, burns Steps on rubber ladder: cuts Fixings: loose, bent, missing, cut
b	-------
c	Rubber body: missing rubber, cracks, chipping, wear, ozone cracks Fixings: corroded
d	No deterioration

(2) Initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis

The determination methods of deterioration for the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis are shown in 3.2 to 3.6 for each fender type. For those checks and diagnoses, the deterioration score is determined by measuring the damage rate of the rubber fenders.

3.2 V-type rubber fender

3.2.1 Method of check/diagnosis and functional evaluation for V-type rubber fender

In the initial check and diagnosis, periodic check and diagnosis, and occasional check and diagnosis of V-type rubber fenders, a field survey is conducted, and the function is evaluated and recorded as follows. In the field survey of V-type rubber fenders, the deterioration of each part is classified, a measurement of the damaged part is carried out for the rubber body, and the deterioration rank is assessed for the fixings. Based on the results, for the rubber body, the damage rate (%) is calculated from the breakage length or area, and the deterioration score is determined. The deterioration rank of fixings is determined based on the condition of the parts. These results are entered on a checklist and saved as a record. The procedure is shown below.

(1) Preparation of layout

Number the rubber fender to identify where in the facility the fenders to be checked are located and place them on the overall floor plan of the facility. Specifically, see Appendix A: Fender Control Chart (Example).

(2) Preparation of the check sheet

Appendix B: Standard form of fender check and diagnosis may be used.

(3) Investigation

Perform an investigation of deterioration visually or using a scale. A picture or sketch is desirable.

(4) Classification of the deteriorated part

The deteriorated parts are classified into rubber bodies and accessories (fixings).

(5) Classification of the deterioration mode

Chapter 2, Section 2.2.2 Deterioration modes of V-type rubber fenders is taken as a reference.

(6) Calculation of the damage rate

Refer to Section 3.2.2 Damage rate. See Appendix C: Examples of determining deterioration score.

(7) Determining deterioration score and deterioration rank

Refer to Section 3.2.3 Deterioration score and ranks.

(8) Check sheet entry

Fill in the check sheet according to Section 3.2.4.

(9) Measures

Take measures based on Chapter 4.

The method of check/diagnosis and functional evaluation is shown in Fig. 3.2.1.

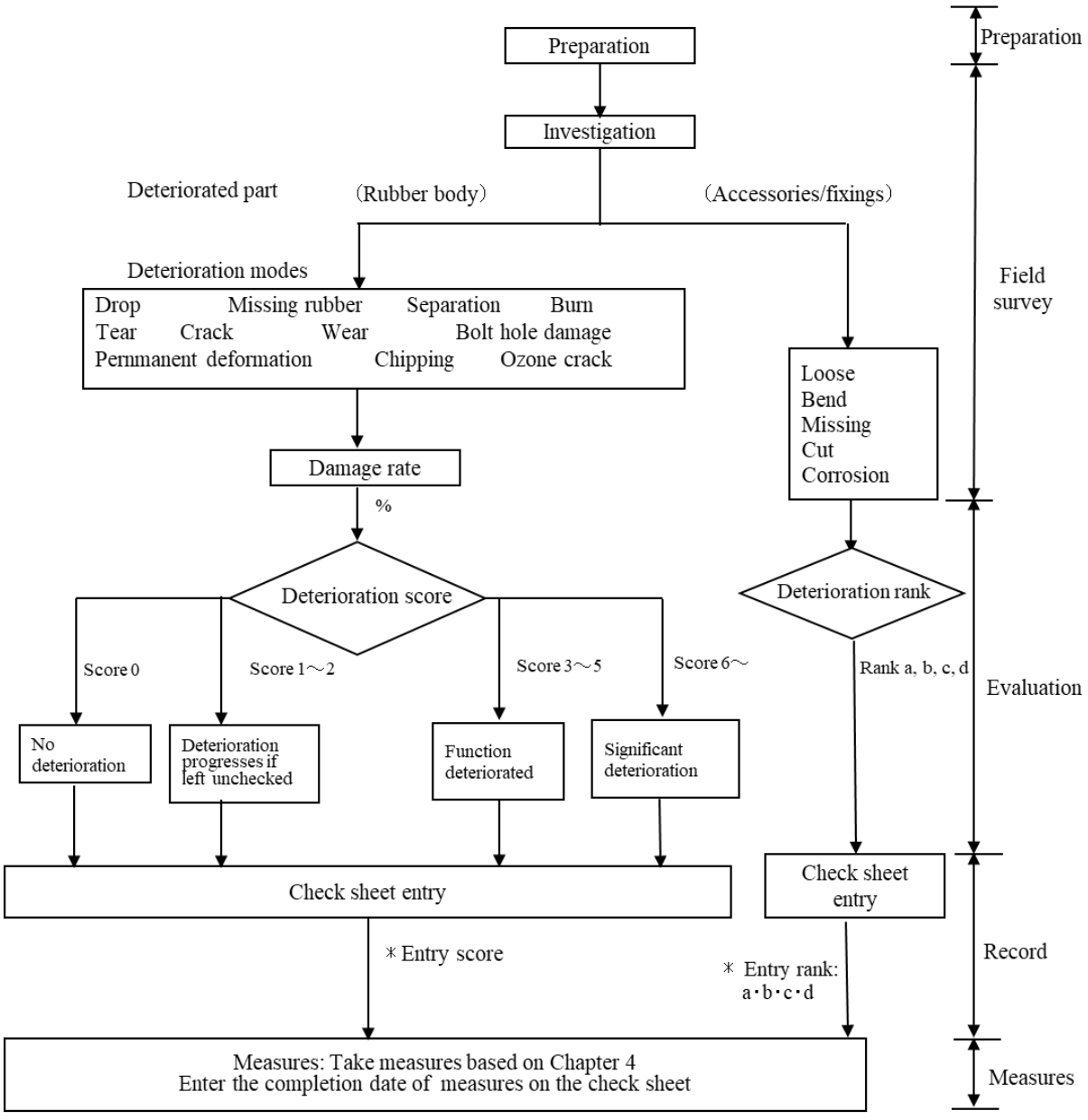


Fig. 3.2.1 Evaluation flow of check/diagnosis for V-type rubber fenders

3.2.2 Damage rate of V-type rubber fender by field survey

V-type rubber fenders are classified into straight bodies and circular bodies with V-shaped body sections. The

dimensions of the damaged part on the rubber body are measured, and the respective damage rates are calculated from the damaged length or damaged area. Additionally, with regard to the removed V-type rubber fenders, it is determined whether re-installation is possible according to the state of bolt hole damage.

(1) Damage rate of V-type rubber fender

1) Length and area of damage

For tears, permanent deformation, cracks, and separation, the damage rate is calculated from the damage length. The damage length is the sum of the projected lengths of damage to the longitudinal axis. This is written as damage length $\{L_1, L_2, \ldots\}$.

For drops, missing rubber, chipping, wear and burns, the damage rate is calculated from the damaged area. The area of damage is the product of the length and width of the damaged part.

For calculation of damage length, the following matters are considered.

a. More than one damage point

As for L_1 and L_3 shown in Fig. 3.2.2, damages occurring in the same part are calculated only when the projection length to longitudinal axis is longer (in the example, L_3, $L_1 < L_3$). L_1 is considered to be included in the L_3 part.

b. Damage perpendicular to the longitudinal axis of rubber fender

If cracking occurs in the direction perpendicular to the longitudinal axis of the rubber fender, as shown in L_4 in Fig. 3.2.2, it is not included in the calculation of damage length because it does not affect the deformation of the rubber body.

c. Inclined damage

As shown in the L_3 part shown in Fig. 3.2.3, if the damage is inclined, measure the projected length (L_6) to the longitudinal axis.

d. Combination of damages

- If a crack is continuous with a tear, include it in the tear and use the length of damage.
- If missing rubber is continuous to the drop, include the drop and use it as the area of damage.
- When a tear and drop coexist, let each be the length of damage and the area of damage.
- In the case of combinations other than the above, let each be the length of damage and the area of damage.

e. Separation

- Separation is taken as the total length of the damage generated on one side.
- If there are separations on both sides, select the longer one for the total length.

2) Calculation of the damage rate

The damage rate is the ratio of damaged length to the length of the fender contacting face or the ratio of damaged area to the fender contacting face.

a. Tears, Permanent deformation, Cracks and Burns

$$\text{Damage rate (\%)} = \frac{\text{Total damage length}}{\text{Length of fender contacting face}} \times 100 \tag{3.2.1}$$

b. Separation

$$\text{Damage rate (\%)} = \frac{\text{Total separated length}}{\text{Length of fixing flange}} \times 100 \tag{3.2.2}$$

c. Drops, Missing rubber, Chipping, Wear

$$\text{Damage rate (\%)} = \frac{\text{Total damaged area}}{\text{Area of fender contacing face}} \times 100 \tag{3.2.3}$$

3) Example of damage rate calculation

Examples of damage rate calculations for drops, tears and separation are shown below.

a. Tears, Permanent deformation, Cracks and Burns

As shown in Fig. 3.2.2, when several damage types occur, measure the damage rate by measuring the length $\{L_1, L_2, L_3, L_4\}$ of each crack. When it occurs in the same part as in the L_1 part and the L_3 part, the longer L_3 is taken. There is no damage length (L_4) in the direction perpendicular to the longitudinal axis. Therefore, L_4 is ignored.

$$\text{Damage rate (\%)} = \frac{\{L_2 + L_3\}}{L} \times 100 \tag{3.2.4}$$

As shown in Fig. 3.2.3, when the crack (L_5) is oblique, the projection length (L_6) to the longitudinal axis is measured.

$$\text{Damage rate (\%)} = \frac{\{L_6\}}{L} \times 100 \tag{3.2.5}$$

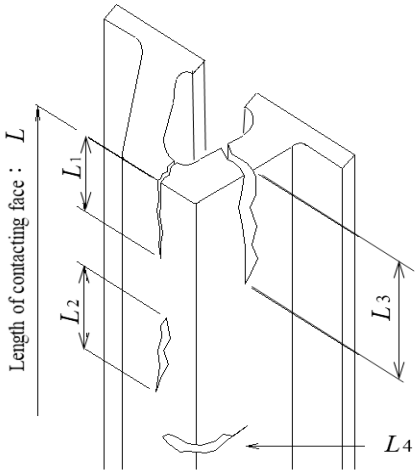


Fig. 3.2.2 Damage measurement (Longitudinal crack)

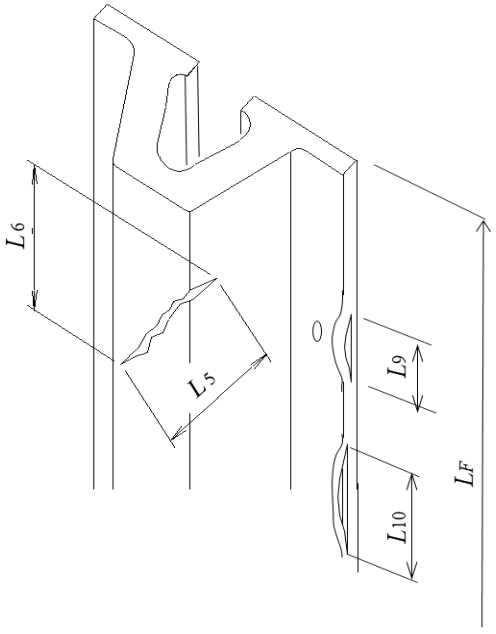


Fig. 3.2.3 Damage measurement (Oblique crack)

b. Drops, Missing rubber, Chipping, Wear

As shown in Fig. 3.2.4, if bulky damage occurs, measure the damage rate by measuring the length $\{L_7, L_8\}$ and width $\{W_1, W_2\}$ of each damage type.

$$\text{Damage rate (\%)} = \frac{\{L_7 \times W_1 + L_8 \times W_2\}}{L \times W} \times 100 \tag{3.2.6}$$

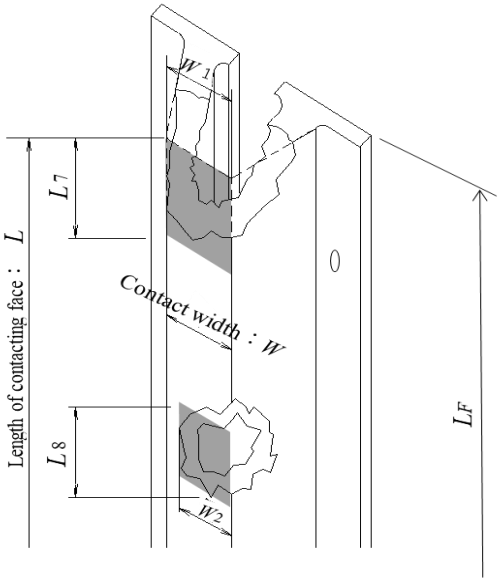


Fig. 3.2.4 Damage measurement (Drops, Missing rubber, Chipping, Wear)

c. Separation

As shown in Fig. 3.2.5 and Fig. 3.2.6, when rubber separation occurs in the fixing flange, measure the damage rate by measuring the length (L_9, L_{10}) of rubber separated from the embedded steel plate.

$$\text{Damage rate (\%)} = \frac{\{L_9 + L_{10}\}}{\text{Total length of fixing flange } \{\Sigma L_F\}} \times 100 \qquad (3.2.7)$$

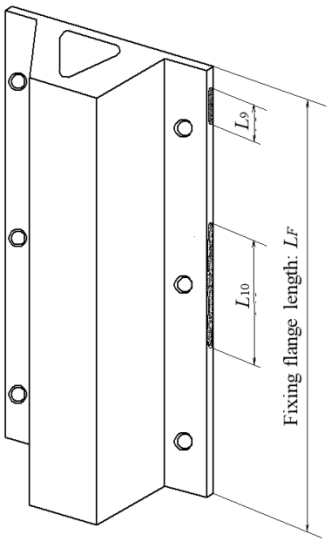


Fig. 3.2.5 Damage measurement (Separation-Single flange)

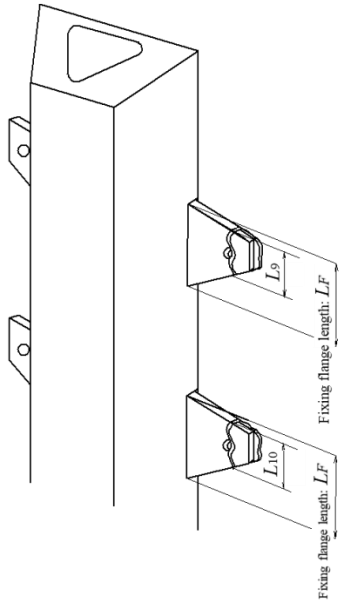


Fig. 3.2.6 Damage measurement (Separation-Multiple flange)

(2) Damage rate of circular rubber fender

1) Length and area of damage

For tears, permanent deformation, cracks, and separation, the failure rate is calculated from the damage length. The damage length is the sum of the lengths of damage. This is written as damage length { L_1, L_2,…}.

For drops, missing rubber, chipping and wear, the damage rate is calculated from the damage area. The area of damage is the product of the length and width of the damaged part.

For the calculation of damage length, the following matters are considered.

a. Multiple non-adjacent damages

If there are multiple non-adjacent damages, as shown in L_1 and L_2 in Fig. 3.2.7, then the total length of damage is taken as the damage length.

b. Multiple adjacent damages

As shown in Fig. 3.2.7, when damages are adjacent as in L_1 and L_3, only the longer damage is calculated, and it is considered that L_3 is included in L_1.

c. Combination of damages

- If a tear is continuous with a crack, include it in the tear and use the length of the damaged area.
- If a drop is continuous to missing rubber, include the drop and use it as the area of damage.
- When a tear and a drop coexist, let each be the length and the area of the damage.
- In the case of combinations other than the above, let each be the length and the area of damage.

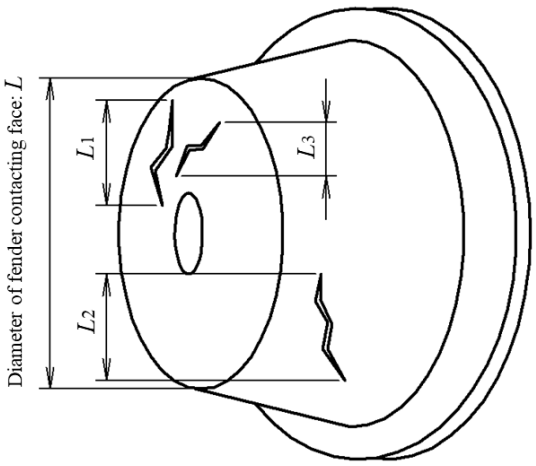


Fig. 3.2.7 Damage measurement
(tears, permanent deformation, cracks, separation and burns - Circular fender)

2) Calculation of the damage rate

The damage rate is indicated by the ratio of the diameter of the fender contacting the face to the length of damage or by the ratio of the area of the fender contacting the face and damaged area.

a. Tears, Permanent deformation, Cracks, Separation and Burns

$$\text{Damage rate (\%)} = \frac{\text{Damage length } \{L_1 + L_2 + \cdots\}}{\text{Diametet of fender contacting face}\{L\}} \times 100 \tag{3.2.8}$$

b. Drops, Missing rubber, Chipping, Wear

$$\text{Damage rate (\%)} = \frac{\text{Total damaged area}}{\text{Area of fender contacing face}} \times 100 \tag{3.2.9}$$

3) Example of damage rate calculations

Examples of damage rate calculations are shown below.

a. Tears, Permanent deformation, Cracks, Separation and Burns

As shown in Fig. 3.2.7, when several damage types occur, measure the damage rate by measuring the length $\{L_1, L_2, L_3\}$ of each crack. When it occurs in the same part as in the L_1 part and the L_3 part, the longer L_1 is taken.

$$\text{Damage rate (\%)} = \frac{\{L_1+L_2\}}{L} \times 100 \tag{3.2.10}$$

b. Drops, Missing rubber, Chipping and Wear

As shown in Fig. 3.2.8, if bulky damage occurs, measure the damage rate by measuring the length $\{L_4, L_6\}$ and width $\{L_5, L_7\}$ of each damage type.

$$\text{Damage rate (\%)} = \frac{\{L_4 \times L_5 + L_6 \times L_7\}}{(\pi \times L^2/4)} \times 100 \tag{3.2.11}$$

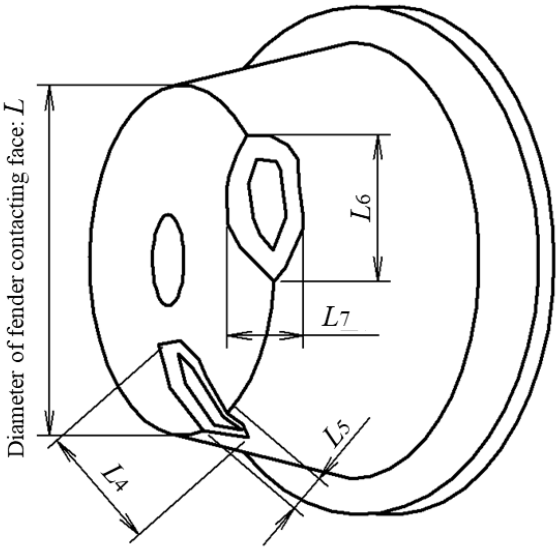


Fig. 3.2.8 Damage measurement
(Drops, Missing rubber, Chipping and Wear - Circular fender)

(3) Re-installing removed rubber fender

If damage has occurred to the rubber fender fixing holes (holes through which the fixing bolt passes through the fixing flange), determine whether re-installation is possible based on Table 3.2.1. Re-installation is not recommended when damage occurs in one or more places. When making this judgement, you may refer to Photo 3.2.1 and Photo 3.2.2.

Table 3.2.1 Judgement of bolt hole damage (V-type rubber fender)

Judgement	Bolt hole condition
Re-installation not recommended	Severe corrosion occurs in the entire hole accompanied by a reduction in plate thickness (hole deformation).
Re-installable	There is no corrosion or deformation in the fixing hole, or corrosion is observed but is partial.

Photo 3.2.1 Re-installation not recommended (Example)

If the coated rubber is peeled off and the iron plate is exposed but there is no decrease in thickness, the failure rate is calculated as separation.

Photo 3.2.2 Re-installable (Example)

3.2.3 Functional evaluation

The functional evaluation of a V-type rubber fender is divided into the functional deterioration of the rubber body and the deterioration rank of the accessories. The score of functional deterioration of the rubber body is comprehensively judged considering the age of the fenders, the structure type of the quay, and the usage condition of the ship. The degree of deterioration of accessories is determined to be the deterioration ranking.

Rubber body:

The score of functional deterioration of the rubber body is determined by dividing the damage rate into six stages and calculating the deterioration score that is obtained by adding the score shown for each deterioration mode and damage rate.

Accessories:

The deterioration rank of accessories (fixings) is determined by dividing the visual condition of the part/member into four stages.

(1) Deterioration score of rubber body

1) Method to score the deterioration

For the deterioration score of the rubber body, the score shown in Table 3.2.2 is added by each deterioration mode and damage rate. When there are two or more deterioration modes among (1) to (11), only the two larger scores are added, and the maximum ceiling is 12 points.

Table 3.2.2 Deterioration score table of rubber body (V-type rubber fenders)

Deterioration mode \ Damage rate	40% or more	30~39%	20~29%	10~19%	1~9%	0%
(1) Drop (Area)	6	6	6	4	2	0
(2) Tear (Length)	6	6	6	4	2	0
(3) Permanent deformation (Length)	6	6	6	4	2	0
(4) Missing rubber (Area)	3	2	1	0	0	0
(5) Crack (Length)	3	2	1	0	0	0
(6) Chipping (Area)	3	2	1	0	0	0
(7) Separation (Length)	3	2	1	0	0	0
(8) Wear (Area)	1	1	1	0	0	0
(9) Burn (Length)	6	6	6	4	2	0
(10) Bolt hole damage	Re-installation not recommended			Re-installable		
	6			0		
(11) Ozone crack	Age 20 years or more			Age less than 20 years		
	1			0		

2) Functional evaluation

The functional evaluation of the rubber body is based on the deterioration score based on Table 3.2.3.

Table 3.2.3 Functional evaluation of rubber body (V-type rubber fenders)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration score	Functional evaluation
6 points or more	Significant functional deterioration
3~5 points	Functional deterioration started
1~2 points	Function will deteriorate if left unchecked
0 points	No functional deterioration

For measures, see Table 4.2.1 in 4.2.1 Measures for rubber body.

(2) Deterioration rank of accessories (fixings)

The deterioration rank of fixings is judged based on the condition of parts and members based on Table 3.2.4.

Table 3.2.4 Function evaluation of fixings (V-type rubber fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Loose, Bent, Missing and/or Cut
b	― ― ―
c	Corrosion observed
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

3.2.4 Check sheet and record

Regarding the deterioration that has occurred in the rubber body and accessories, record the state of deterioration for each V-type rubber fender on the check sheet. Fig. 3.2.9 shows an example of a check sheet prepared for the case of Photo C.10 in Appendix C: Evaluation of Functional Deterioration.

Check sheet of V-type rubber fender

Location	○○ County	Date of installation	○/ ○ / ○
Name of port	○○ Port	Name of quay	-5.0 m Wharf No. ○○
Fender size	○○ 400 H×1500 L	Fender ID	No.1

1. Rubber body

Date of inspection	○ / ○ / ○		
Inspector	John F. Kowan		
Items	Inspection result	Items	Inspection result
(Det. Mode) (1) Drop (2) Tear (3) Permnt. Deform. (4) Missing rubber (5) Crack (6) Chipping (7) Separation (8) Wear (9) Burn (10) Bolt hole damage (11) Ozone crack	Det. mode / Length or area of damage / Damage rate / Det. score (4) 1750 cm^2 47% 3 (7) 80 cm 53% 3 Total 6	(1) Loose (2) Bent (3) Missing (4) Cut (5) Corroded	a (One bolt missing)
Deterioration score	6	Measure for accessories	Bolt replacement
Considerations when deterioration score is 3~5. If checked, replacement is recommended.	a) Age 20 years or more ☐ b) Mooring 10,000 hours or more ☐ c) Load sensitive quay structure ☐		
Measure for rubber body	Replacement No (Yes) (Date of completion:)		No (Yes) (Date of completion:)

2. Accessories (fixings)

3. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation		Missing rubber: $\frac{\text{Total chunked out area}}{\text{Area of fender contacing face}} \times 100 = \frac{25 \times 70}{25 \times 150} \times 100 = 47\%$ →Deterioration score 3 points Separation: $\frac{\text{Total separated length}}{\text{Length of fixing flange}} \times 100 = \frac{80}{150} \times 100 = 53\%$ →Deterioration score 3 points

Fig. 3.2.9 Example of check sheet (V-type rubber fender)

3.3 Rubber fender with fender panel

3.3.1 Method of check/diagnosis and functional evaluation for rubber fender with panel

In the initial check and diagnosis, periodic check and diagnosis, and occasional check and diagnosis of rubber fenders with a panel, a field survey is conducted, and the function is evaluated and recorded. The details of the check and diagnosis and functional evaluation procedures conform to 3.2 V-type rubber fenders. The flow of check/diagnosis and functional evaluation is shown in Fig. 3.3.1.

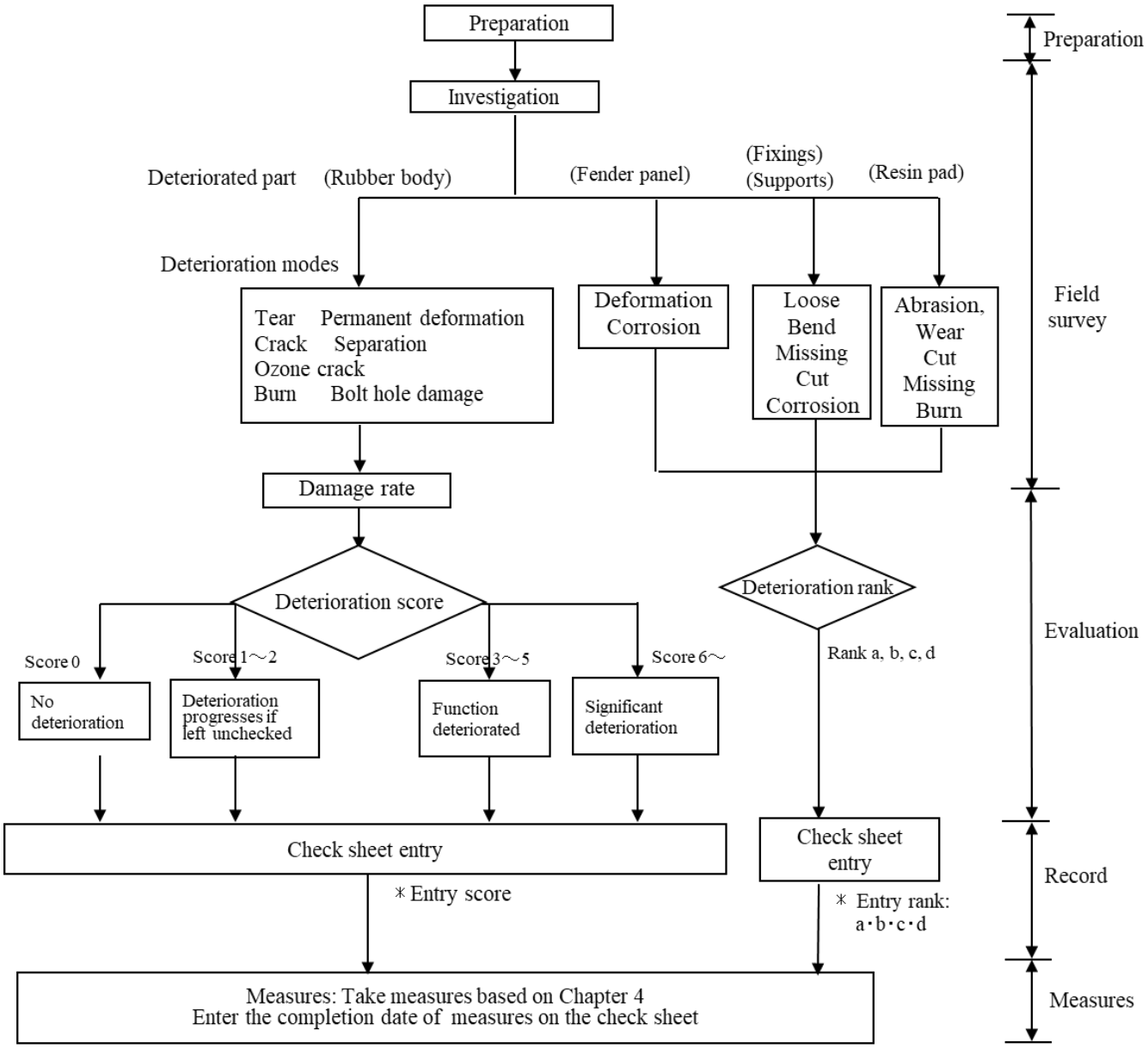


Fig. 3.3.1 Evaluation flow of check/diagnosis for rubber fender with fender panel

3.3.2 Damage rate by field survey for fender with panel

Rubber fenders with panels can be sorted into longitudinal types and circular types according to the shape of the rubber body. The dimensions of the damaged part generated in the rubber body are measured, and the damage rate is calculated from the damaged length. In addition, with regard to a removed rubber fender and panel, it is determined whether it can be re-installed based on the state of the bolt holes.

(1) Damage rate of longitudinal rubber fender with panel

1) Length of damage

For tears, permanent deformation, cracks, separation and burns, the damage rate is calculated from the damage length. The damage length is the sum of the lengths of damaged parts, which is written as $\{L_1, L_2 \ldots\}$.

The calculation of the damage length is performed in consideration of the following matters.

a. The rubber body is a group of modules (A and B legs)

As shown in Fig. 3.3.2, when the rubber body is divided into one pair (A and B legs), each leg is evaluated.

b. Plural damage

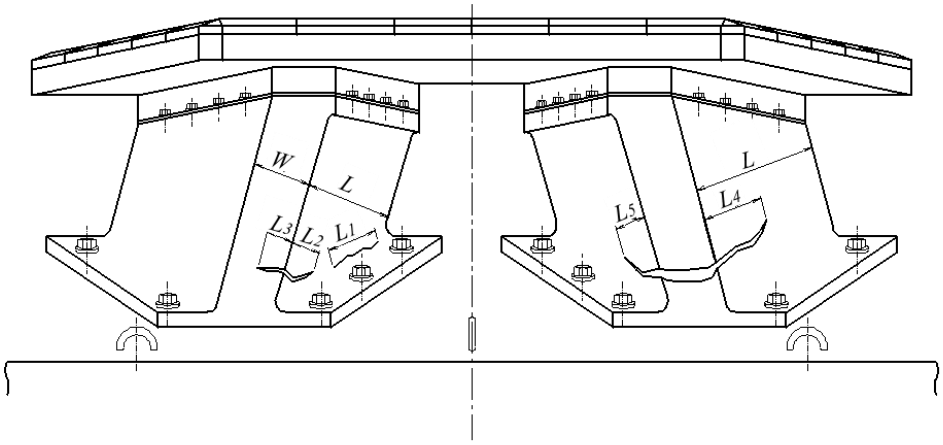
As shown in the A leg of Fig. 3.3.2, when there are multiple damage types, the total projected lengths of the damages will be the damage length.

c. Single damage on both sides of the body

As shown in the B leg of Fig. 3.3.2, for the cracks occurring in the same part, only the projection length to longitudinal axis is calculated, so the L_5 part is included in the L_4 part.

d. Combination of damages

If a crack is continuous with a tear, include it in the tear to calculate the damaged length.



A leg B leg

Note: These leg sides are expanded to show both sides

Fig. 3.3.2 Damage measurement (longitudinal shape with panel)

2) Calculation of the damage rate

The damage rate is indicated by the ratio of the damage length to the length of the rubber body.

$$\text{Damage rate (\%)} = \frac{\text{Damage length } \{L_1 + L_2 + \cdots\}}{\text{Length of rubber body } \{L\}} \times 100 \tag{3.3.1}$$

3) Example of damage rate calculation

Cracks and tears are shown as representative calculation examples of the damage rate.

a. Cracks, Permanent deformation, Separation

As shown in Fig. 3.3.2 (A leg), when several cracks are generated, calculate the damage rate by measuring the length $\{L_1, L_2, L_3\}$ of each crack.

$$\text{Damage rate (\%)} = \frac{\{L_1+L_2+L_3\}}{L} \times 100 \tag{3.3.2}$$

b. Tears

As shown in Fig. 3.3.2 (B leg), if tears are occurring, calculate the damage rate by measuring the length $\{L_4, L_5\}$ of each damage. If it occurs in the same part as in the L_4 part and the L_5 part, the longer L_4 is taken.

$$\text{Damage rate (\%)} = \frac{L_4}{L} \times 100 \tag{3.3.3}$$

(2) Damage rate of circular rubber fender with panel

1) Length of damage

For tears, permanent deformation, cracks, separation and burns, the damage rate is calculated from the damage length. The damage length is the sum of the lengths of damaged parts, which is written as $\{L_1, L_2 \ldots\}$. The calculation of the damage length is performed in consideration of the following matters.

a. Multiple remote damages

As shown in L_1, L_3 and L_4 in Fig. 3.3.3, when there are multiple damages, the total projected lengths of the damages will be the damage length.

b. Multiple adjacent damages

If the damage consists of multiple cracks adjacent to each other, as shown in L_1 and L_2 in Fig. 3.3.3, only the larger crack is taken as the length of damage cracks.

c. Combination of damages

If a crack is continuous with a tear, include it in the tear to calculate the damage length.

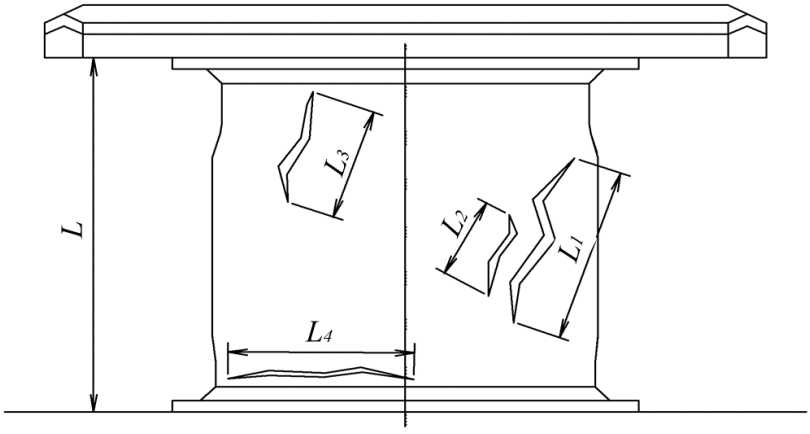


Fig. 3.3.3 Damage measurement (Circular shape with panel)

2) Calculation of the damage rate

The damage rate is indicated by the ratio of the damage length to the length of the rubber body.

$$\text{Damage rate (\%)} = \frac{\text{Damage length } \{L_1+L_2+\cdots\}}{\text{Length of rubber body } \{L\}} \times 100 \tag{3.3.4}$$

3) Example of damage rate calculation

Cracks and tears are shown as representative calculation examples of the damage rate. As shown in Fig. 3.3.3, if damage occurs, the damage rate is calculated by measuring the length { L_1, L_2, L_3, L_4} of each damage. If damage occurs in the adjacent group as in the L_1 part and the L_2 part, the longer L_1 is taken.

$$\text{Damage rate (\%)} = \frac{\{L_1 + L_3 + L_4\}}{L} \times 100 \tag{3.3.5}$$

(3) Re-installing removed rubber fender

If damage has occurred to the rubber fender fixing holes (holes through which the fixing bolt passes through the fixing flange), determine whether re-installation is possible based on Table 3.2.1. Re-installation is not recommended when damage occurs in one or more places. When making this judgement, you may refer to Photo 3.2.1 and Photo 3.2.2.

3.3.3 Functional evaluation of rubber fender with panel

The functional evaluation of a rubber fender with panel is divided into the functional deterioration of the rubber body and the deterioration rank of the accessories. The score of functional deterioration of the rubber body is comprehensively judged in consideration of the age of the fenders, the structure type of the quay, and the usage condition of the ship. The degree of deterioration of the accessories is determined as the deterioration ranking.

Rubber body:

The score of functional deterioration of the rubber body is determined by dividing the damage rate into six stages and calculating the deterioration score that is obtained by adding the score shown for each deterioration mode and damage rate.

Accessories:

The deterioration rank of accessories (fender panel, fixings, supports, resin pad) is determined by dividing the visual condition of the part/member into four stages.

(1) Deterioration score of rubber body

1) Method to score the deterioration

For the deterioration score of the rubber body, the score shown in Table 3.3.1 is added by each deterioration mode and damage rate. When there are two or more deterioration modes among (1) to (7), only the two larger scores are added, and the maximum ceiling is 12 points.

Table 3.3.1 Deterioration score table of rubber body (Rubber fender with panel)

Deterioration mode \ Damage rate	40% or more	30~39%	20~29%	10~19%	1~9%	0%
(1) Crack (Length)	6	4	4	3	1	0
(2) Tear (Length)	6	6	6	4	2	0
(3) Permanent deformation (Length)	6	6	6	4	2	0
(4) Separation (Length)	3	2	1	0	0	0
(5) Burn (Length)	6	6	6	4	2	0
(6) Bolt hole damage	Re-installation not recommended			Re-installable		
	6			0		
(7) Ozone crack	Age 20 years or more			Age less than 20 years		
	1			0		

2) Functional evaluation

The functional evaluation of the rubber body is based on the deterioration score based on Table 3.3.2.

Table 3.3.3 Functional evaluation of rubber body (Rubber fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration score	Functional evaluation
6 points or more	Significant functional deterioration
3~5 points	Functional deterioration started
1~2 points	Function will deteriorate if left unchecked
0 points	No functional deterioration

For measures, see Table 4.2.1 in 4.2.1 Measures for rubber body.

(2) Deterioration rank of accessories (fender panel, fixings, supports, resin pad)

1) Fender panel

The deterioration rank of the fender panel is judged based on the condition of part and member based on Table 3.3.3. When making this judgement, you may refer to Photo 3.3.1 and Photo 3.3.2.

Table 3.3.3 Functional evaluation of fender panel (Rubber fender with panel)
(Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	The deformation is too large for further use. Widespread severe corrosion accompanied by a decrease in steel plate thickness. (See Photo 3.3.1)
b	― ― ―
c	Miner deformation but can be used continuously. Corrosion is observed but partial. (See Photo 3.3.2)
d	No deformation. No paint deterioration and almost no corrosion.

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

Photo 3.3.1 Example of damage rank “a” of fender panel corrosion

Photo 3.3.2 Example of damage rank “c” of fender panel corrosion

2) Fixings

The deterioration rank of fixings is judged based on the condition of the part and member based on Table 3.3.4. When making this judgement, you may refer to Appendix D: Example of deterioration rank for fixings.

Table 3.3.4 Functional evaluation of fixings (Rubber fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Loose, Bent, Missing and/or Cut
b	— — —
c	Corrosion observed
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

3) Supports

The deterioration rank of supports is judged based on the condition of the part and member based on Table 3.3.5.

Table 3.3.5 Functional evaluation of supports (Rubber fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Significant bends, cuts or corrosion; further use is impossible
b	— — —
c	Bent and corroded, but further use possible
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

4) Resin pad

The deterioration rank of the resin pad is judged based on the condition of the part and member based on Table 3.3.6. When making this judgement, you may refer to Photo 2.3.17 to Photo 2.3.20.

Table 3.3.6 Functional evaluation of resin pad (Rubber fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Cut, missing and/or burned. Severe abrasion and wear reaching to the bolt head.
b	― ― ―
c	Minor abrasion or wear was observed, but further use is possible.
d	No deterioration

For measures, see Table 4.2.2 in 4.2.3 Measures for accessories.

3.3.4 Check sheet and record

Regarding the deterioration that has occurred in the rubber body and accessories, record the state of deterioration for each rubber fender with panel on the check sheet. Fig. 3.3.4 shows an example of the check sheet.

Check sheet of Rubber fender with Panel

Location	○○ County	Date of installation	○/ ○ / ○
Name of port	○○ Port	Name of quay	-10.0 m Wharf No. ○○
Fender size	○○1000 H×1500 L	Fender ID	No.7

1. Rubber body

Date of inspection	○ / ○ / ○		
Inspector	Donald J. Port		
Items	Inspection result		
〔Det. mode〕 (1) Tear (2) Crack (3) Permnt. Deform. (4) Separation (5) Burn (6) Bolt hole damage (7) Ozone crack	Det. mode / Length or area of damage / Damage rate / Det. score (1) 20 cm 13% 3 (2) 80 cm 53% 6 Total 9		
Deterioration score	9		
Considerations when deterioration score is 3~5. If checked, replacement is recommended.	a) Age 20 years or more ☐ b) Mooring 10,000 hours or more ☐ c) Load sensitive quay structure ☐		
Measure for rubber body	Replacement No (Yes) (Date of completion:)		

2. Fender panel

Items	Inspection result
(1) Deformation (2) Corroded	c (Partial bending of steel plate) a Severe and widespread corrosion
Measurement for fender panel	Replacement No (Yes) (Date of completion:)

3. Fixings

Items	Inspection result
(1) Loose (2) Bent (3) Missing (4) Cut (5) Corroded	c (One nut loose) a (One bolt missing)
Measure	Re-tighten nut Replacement for missed bolt No (Yes) (Date of comp.)

4. Supports

Items	Inspection result
(1) Bent (2) Cut (3) Corroded	a (One shackle bend) a (Severe chain corrosion)
Measure	Replacement No (Yes) (Date of comp.)

5. Resin pad

Items	Inspection result
(1) Wear (2) Abrasion (3) Cut (4) Missing	c (Wear on whole surface) a (2 pads missing)
Measure	Replacement of missed pad No (Yes) (Date of comp.)

6. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation		・Damage rate of tear＝20/150×100＝13% →Deterioration score: 3 ・Damage rate of crack＝80/150×100＝53% →Deterioration score: 6

Fig. 3.3.4 Example of check sheet (Rubber fender with panel)

3.4 Pneumatic fender

3.4.1 Method of check/diagnosis and functional evaluation for pneumatic fender

In the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis of pneumatic fenders, a field survey is conducted, and function is evaluated and recorded. Since the pneumatic fender absorbs the berthing energy of a ship using the elasticity of air filled in a rubber body, the deterioration level and airtightness of the rubber body are important.

(1) Preparation of the whole layout

To clarify which position in the facility the pneumatic fender to be checked is located, write the number of the pneumatic fender on the overall facility plan. See Appendix A: Fender Maintenance Chart (Example).

(2) Preparation of fender check sheet

Appendix B: Standard form of fender check and diagnosis may be used.

(3) Investigation

Perform visually or use a scale and/or pressure gauge. A picture or sketch is desirable.

(4) Classification of deteriorated parts

Classify the deteriorated parts into the rubber body, air inlet valve, body attachment, and floating attachment (net, mooring bracket) or fixed type attachment with panel (fender panel, fixings, supports, resin pad).

(5) Classification of deterioration mode

Refer to Section 2.4.2 in Chapter 2 Deterioration modes of pneumatic fender.

(6) Measurement and calculation of air pressure (internal pressure) and temperature

Conduct based on 3.4.2 Deterioration level and degree of airtightness maintenance.

(7) Judgement of deterioration level and airtightness

Judge based on 3.4.2 deterioration level and air tightness.

(8) Judgement of functional deterioration and deterioration rank

Judge based on 3.4.3 Functional evaluation.

(9) Check sheet entry

Refer to 3.4.4 Checklist entry.

(10) Measures

Take measures based on Chapter 4.

The flow of check and diagnosis and functional evaluation is shown in Fig. 3.4.1.

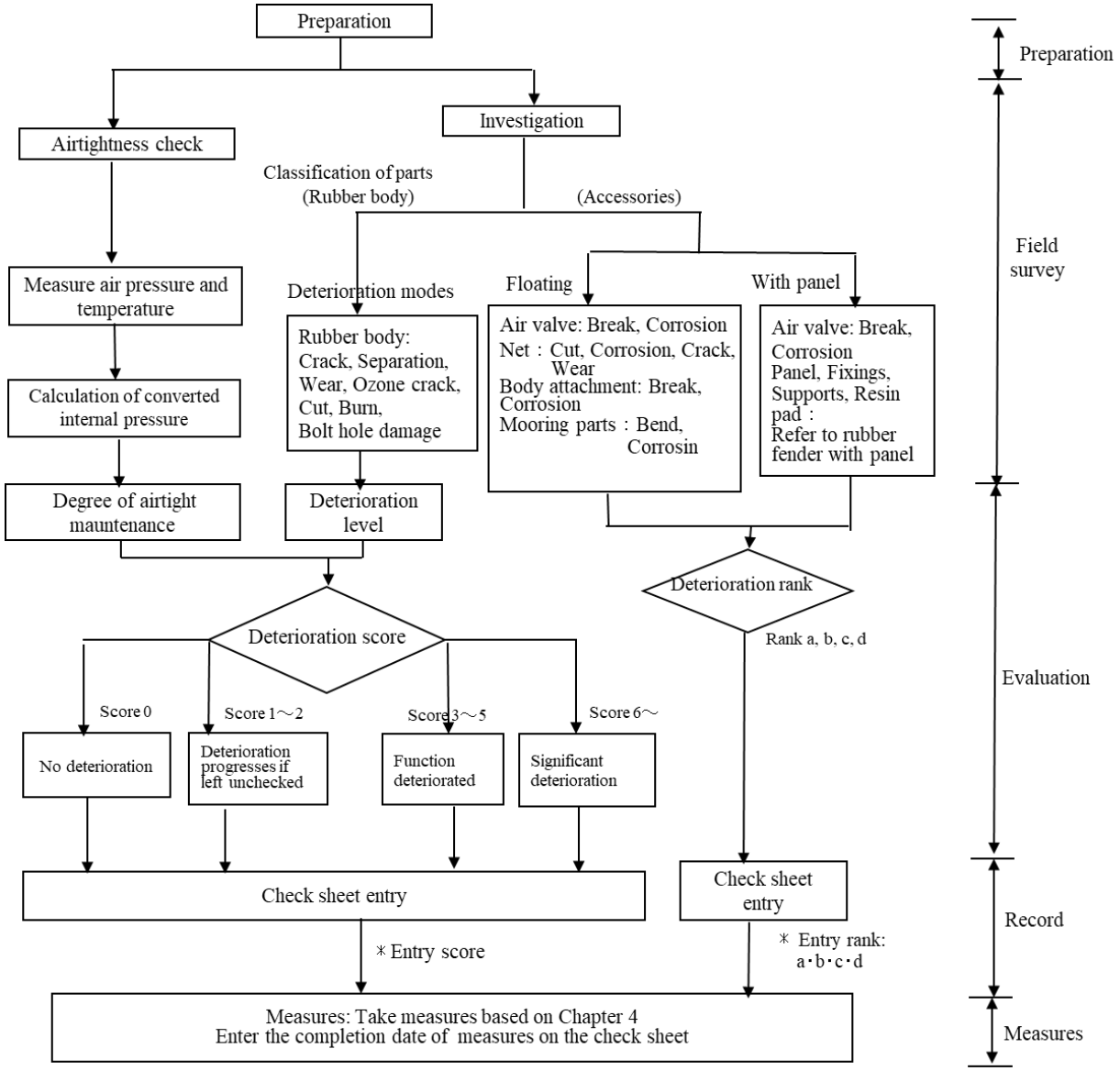


Fig. 3.4.1 Evaluation flow of check/diagnosis for pneumatic fender

3.4.2 Deterioration level and degree of airtightness maintenance

The determination of the deterioration score of the pneumatic fender is performed based on the deterioration level and the degree of airtightness maintenance.

(1) Deterioration level of pneumatic fender body

The deterioration level due to cracks, chipping, wear, ozone cracks, separation, cuts and burns generated in the rubber body of the pneumatic fender is determined by classifying the state of deterioration into six stages based on Table 3.4.1. If damage has occurred to the fixing hole (hole for anchor bolts to fixing flange) of the pneumatic fender, determine the possibility of re-installation based on Table 3.2.1. Re-installation is impossible when damage occurs in one or more places. In addition, in the case of determination, you may refer to photo 3.2.1 and photo 3.2.2.

Table 3.4.1 Deterioration level of pneumatic fender

Deterioration level	Condition of parts and member
Deterioration level I	There are damages or burns in the outer layer, reinforcing layer, and inner layer. The corrosion of the embedded steel plate progresses significantly, separation progresses to the inside of the rubber along the embedded steel plate, and damage such as cut occurs in the inner layer. Not recommended to be re-installed due to bolt hole damage (fixed type).
Deterioration level II	Inner layer rubber has no damages or burns, but reinforcing layer is partially cracked, separated or worn away. There is no air leakage, but embedded steel plate is exposed and corrosion progresses inside rubber.
Deterioration level III	Outer layer rubber is cracked, chipped, separated, worn away or burned, and the reinforcing layer is exposed. There is no air leakage, but the surface rubber covering the embedded steel plate is peeled off, and the embedded steel plate is exposed.
Deterioration level IV	Outer layer rubber is cracked, chipped, separated, worn away or burned (reinforcing layer is not exposed).
Deterioration level V	Ozone cracks have occurred in outer rubber layer.
Deterioration level VI	No damage to rubber body. No separation of embedded steel plate.

(2) Airtightness of pneumatic fenders

When determining the airtightness of the pneumatic fender, the internal pressure and temperature measured at the time are compared with the internal pressure and temperature measured at a previous time. Converted internal pressure is calculated using equation 3.4.1.

$$P_t = (101.3 + P_0) \times \frac{273 + t_t}{273 + t_0} - 101.3 \tag{3.4.1}$$

P_t : Current converted internal pressure (kPa)
P_0 : Previous internal pressure (kPa)
t_t : Current temperature at pressure measurement (°C)
t_0 : Previous temperature at pressure measurement (°C)

The airtightness of pneumatic fenders is determined by dividing the state of converted internal pressure into four levels based on Table 3.4.2.

Table 3.4.2 Degree of airtightness maintenance

Airtightness	Condition of converted inner pressure
Airtight I	Measured air pressure is zero, and air cannot be filled.
Airtight II	Previous setting (or measured) internal pressure exceeds ± 10 kPa.
Airtight III	Within ±10 kPa of previous setting (or measured) internal pressure
Airtight IV	Same as the previously set (or measured) internal pressure.

Note 1) For Airtight II, as a retest, air is filled to the specified internal pressure and left for 24 hours, and then the internal pressure is measured (including the ambient temperature) again. If the converted internal pressure is within ± 5 kPa, it is judged as Airtight III.

Note 2) To compare the measured internal pressure of the pneumatic fender with the specified internal

pressure, calculate the internal measured pressure converted to the temperature at the specified internal pressure using the ambient temperature measured simultaneously. In principle, the internal pressure is set at a Japanese average temperature of 15 °C. However, depending on the usage of the pneumatic fender, it is also possible to set a pre-set temperature for each region or each season.

(3) Check method of air pressure

An example of the measurement method and charging method of the air pressure of a pneumatic fender is be shown below. For details, check the instruction manual of each manufacturer.

1) Floating pneumatic fender

a. Check of air pressure

- Remove the cap ② of the air inlet valve ①.
- Press the air chuck ④ of the pressure gauge ③ against the air inlet valve ① to measure the air pressure.

b. Charging method of air (mid-small size smaller than Φ2000)

- Remove the cap ② of the air inlet valve ①.
- Connect the air-charge device to the compressor.
- Press the air chuck ④ against the air inlet valve ① to fill it with air.
- According to a above, fill up to the target internal pressure while measuring the air pressure.

c. Charging method of air (large size ϕ 2000 or larger)

- Connect the air charge joint ⑤ to the fender. (connection location and method differ depending on the manufacturer)
- Connect the air charging device to the compressor.
- Fill to the target internal pressure while measuring the air pressure by opening and closing the valve of the pressure gauge ⑥.

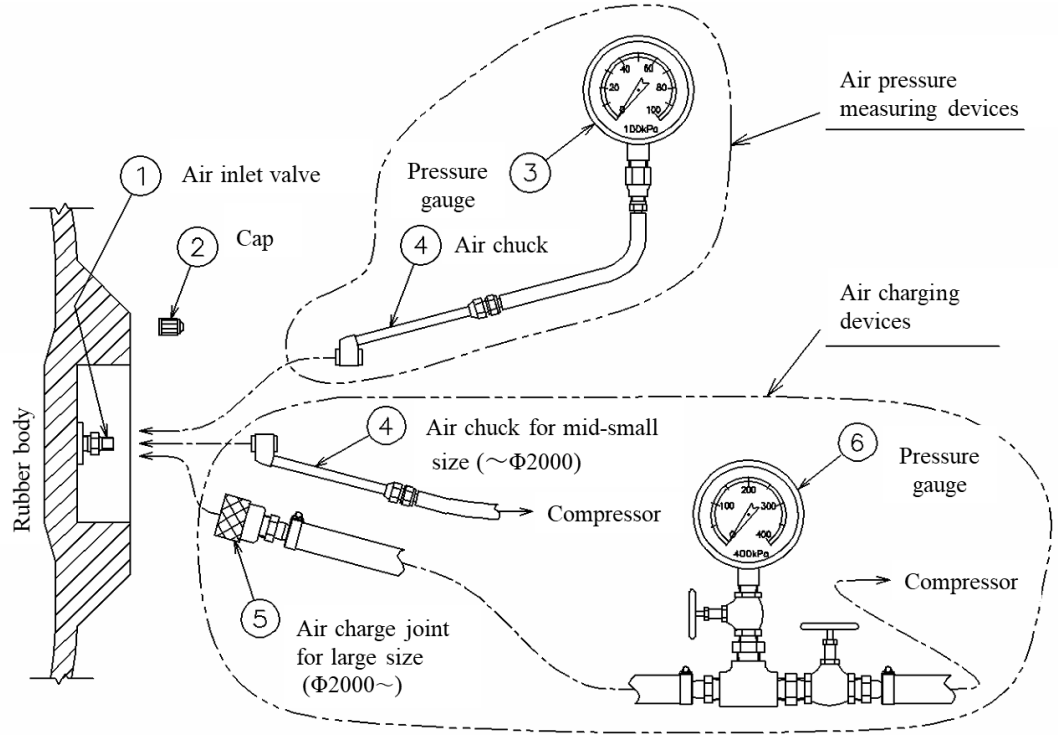


Fig. 3.4.2 Pressure measuring and air charge method (Floating type)

Note) Check and observe the specified internal pressure when measuring or filling air pressure. In addition, when filling with air, be sure to check with a pressure gauge to prevent introducing too much air.

2) Fixed type pneumatic fender with panel

a. Check of air pressure

- Loosen the bolt ⑧ slightly with spanner ⑨ and open the valve protector ⑦.
- Remove the cap ② on the air inlet valve ①.
- Press the air chuck ④ of the pressure gauge ③ against the air inlet valve ① to measure the air pressure.

b. Charging method of air

- Remove the cap ② of the air inlet valve ①.
- Connect the air charge device to the compressor.
- Press the air chuck ④ against the air inlet valve ① to fill it with air.
- According to a above, fill up to the target internal pressure while measuring the air pressure.

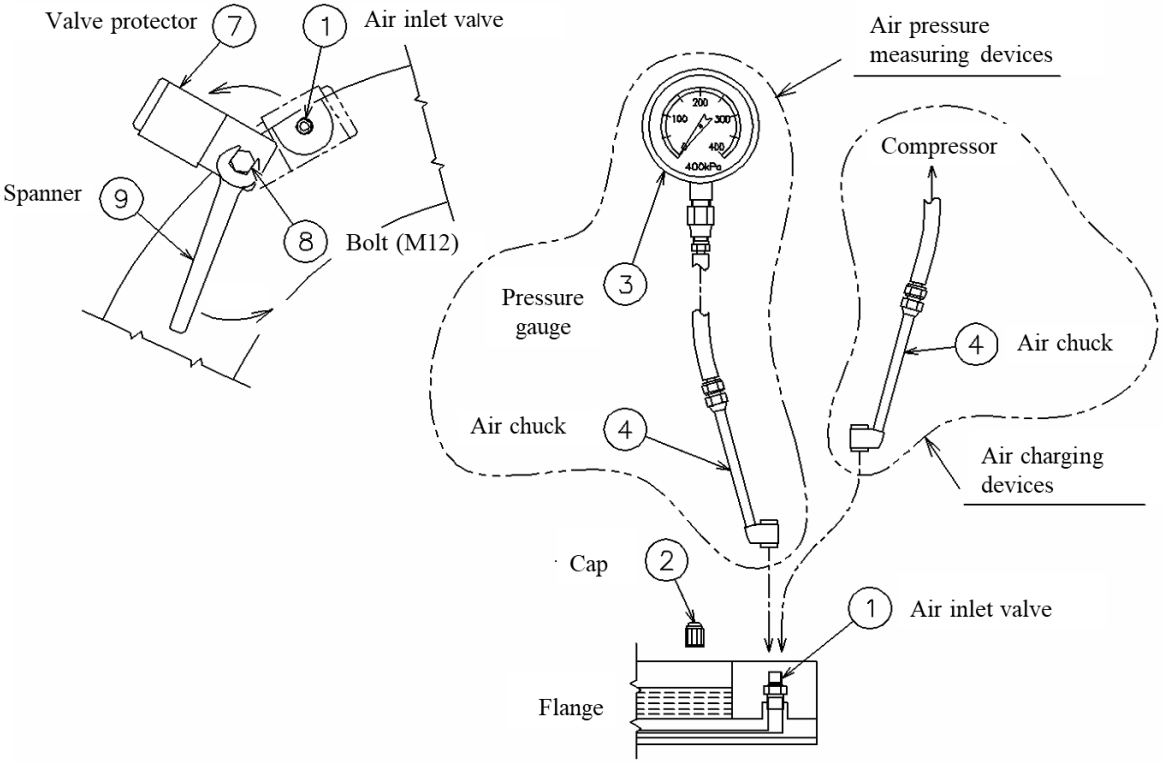


Fig. 3.4.3 Pressure measuring and air charge method (Fixed type with panel)

Note) Check and observe the specified internal pressure when measuring or filling air pressure. In addition, when filling with air, be sure to check with a pressure gauge to prevent introducing too much air.

3.4.3 Functional evaluation for pneumatic fender

The functional evaluation of pneumatic fenders is judged comprehensively from the age of the fenders, structural type of quay, usage of ships, and degree of deterioration of accessories in addition to functional deterioration for the rubber body.

Deterioration score:

The functional deterioration of the rubber body is determined by dividing the deterioration into six levels, the airtightness maintenance level into four levels and adding the score indicated for each deterioration and airtightness

level.

Deterioration rank:

The degree of deterioration of accessories includes air inlet valve, body attachment, floating type attachment (net, mooring parts), and fixed type with fender panel (panel section, fixings, supports, resin pad). Divide the state of parts and members into 4 levels and evaluate.

(1) Deterioration score of the rubber body

1) How to obtain the deterioration score

The deterioration score of the rubber body is calculated by adding the points shown in Table 3.4.3 based on deterioration level and the degree of airtight maintenance.

Table 3.4.3 Deterioration score of rubber body (Pneumatic fender)

Deterioration level/Degree of airtightness maintenance		I	II	III	IV	V	VI
Deterioration score	(1) Deterioration level	6	5	4	2	1	0
	(2) Degree of airtightness maintenance	6	4	1	0	-	-

2) Functional evaluation

Functional evaluation is based on the deterioration score based on Table 3.4.4.

Table 3.4.4 Functional evaluation of rubber body (Pneumatic fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration score	Functional evaluation
6 points or more	Significant functional deterioration
3~5 points	Functional deterioration started
1~2 points	Function will deteriorate if left unchecked
0 points	No functional deterioration

For measures, see Table 4.2.1 in 4.2.1 Measures for rubber body.

(2) Deterioration rank of accessories

1) Air inlet valve

The deterioration rank of the air inlet valve is based on the condition of parts and members in Table 3.4.5.

Table 3.4.5 Deterioration rank of air inlet valve (Pneumatic fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of parts and member
a	There is damage. The progress of corrosion is extensive and the valve cannot be used continuously, or there is air leak.
b	― ― ―
c	There is corrosion, but continued use is possible
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

2) Body attachment

The deterioration rank of the body attachment is evaluated based on Table 3.4.6 based on the

condition of parts and members.

Table 3.4.6 Deterioration rank of body attachment (Pneumatic fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of parts and member
a	There is damage. The progress of corrosion is extensive, and the attachment cannot be used continuously.
b	― ― ―
c	There is corrosion, but continued use is possible
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

3) Floating type attachment

a. Nets

The deterioration rank of a net is judged based on the condition of the parts and members based on Table 3.4.7.

Table 3.4.7 Deterioration rank of net (Pneumatic fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of parts and member
a	There is a disconnection of the net, or the progress of corrosion is extensive, and it cannot be used continuously. The old tyre or rubber sleeve have significant burns and have lost function as a protective member of the fender body.
b	― ― ―
c	There are cuts, wear and/or corrosion, but continued use is possible.
d	No deterioration

For measures, see Table 4.2.3 in 4.2.2 Measures for accessories.

b. Mooring parts

The deterioration rank of mooring parts is judged based on the condition of the part and member based on Table 3.4.8.

Table 3.4.8 Deterioration rank of mooring parts (Pneumatic fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of parts and member
a	There is bending, cutting or progressed corrosion, and the parts cannot be used continuously.
b	― ― ―
c	There is bending and corrosion, but continued use is possible.
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

4) Accessories for fixed type fender with panel

a. Fender panel

The deterioration rank of the fender panel is judged based on the condition of the part and member

based on Table 3.4.9.

Table 3.4.9 Functional evaluation of fender panel (Pneumatic fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	The deformation is too large for further use. Widespread severe corrosion accompanied by a decrease in steel plate thickness. (See Photo 3.3.1)
b	― ― ―
c	Minor deformation but can be used continuously. Corrosion is observed but partial. (See Photo 3.3.2)
d	No deformation. No paint deterioration and almost no corrosion.

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

b. Fixings

The deterioration rank of fixings is judged based on the condition of the part and member based on Table 3.4.10.

Table 3.4.10 Functional evaluation of fixings (pneumatic fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Loose, bent, missing and/or cut fixings were found
b	― ― ―
c	Corrosion observed
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

c. Supports

The deterioration rank of supports is judged based on the condition of the part and member based on Table 3.4.11.

Table 3.4.11 Functional evaluation of supports (Pneumatic fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Significant bends, cuts or corrosion making further use impossible
b	― ― ―
c	Bends and corrosion, but further use is possible
d	No deterioration

d. Resin pad

The deterioration rank of the resin pad is judged based on the condition of the part and member based on Table 3.4.12. When making this judgement, you may refer to Photo 2.3.17 to Photo 2.3.20.

Table 3.4.12 Functional evaluation of resin pad (Pneumatic fender with panel)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Cut, missing or burned pads were found. Severe abrasion and wear reaching to the bolt head.
b	― ― ―
c	Minor abrasion or wear was observed, but further us is possible.
d	No deterioration

For measures, see Table 4.2.2 in 4.2.3 Measures for accessories.

3.4.4 Check sheet and record

Regarding the deterioration that has occurred in the pneumatic fenders and the deterioration that has occurred in each member, the deterioration status is recorded on a check sheet for each pneumatic fender. At the same time, measure and record the air pressure inside the fender. Fig. 3.4.4 and Fig. 3.4.5 show examples of the check sheet.

Check sheet of Pneumatic fender

Location	○○ County	Date of installation	○/ ○ / ○
Name of port	○○ Port	Name of quay	-5 m Wharf No. ○○
Fender size	Pneumatic ϕ 2500×5000 L-40 kPa	Fender ID	No. ○

1. Rubber body

Date of inspection	○ / ○ / ○
Inspector	

Items	Inspection result
[Deterioration mode] Degree of Airtightness maintenance Deterioration level	Det. mode: Airtight; Level: III; Condition: Within ±10 kPa; Det. score: 3 Det. level: IV; Condition: Crack on outer layer; Det. score: 2 Total: 3
	Previous pressure 40 kPa (Temp. 15 ℃) Measured pressure 35 kPa (Temp. 10 ℃) Converted pressure 37.5 kPa
Deterioration score	3
Considerations when deterioration score is 3~5. If checked, replacement is recommended.	a) Age 20 years or more ☐ b) Mooring 10,000 hours or more ☐ c) Load sensitive quay structure ☐
Measure for rubber body	Replacement (No) Yes (Date of completion:)

2. Air inlet valve 3. Body attachment

Items	Inspection result
Air inlet valve (1) Damage (2) Corroded	a Deformation of valve
Body attachment (1) Damage (2) Corroded	c. Corrosion around nozzle
Measurement	Replacement No (Yes) (Date of completion:)

4. Net 5. Mooring parts

Items	Inspection result	Items	Inspection result
(1) Corrosion (2) Cuts (3) Cracks (4) Wear	a (Remarkable corrosion) a (Cut of chain net)	(1) Bends (2) Cuts (3) Corroded	a (Severe corrosion)
Measure	Replacement No (Yes) (Date of comp.)	Measure	Replacement No (Yes) (Date of comp.)

6. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation	 Deterioration level Deterioration score Level IV : Crack at outer layer 2 points Airtight III : Within ±10 kPa of previous pressure 1 point Pressure conversion = (101.3+40)×(273+10)/(273+15)−101.3 = 37.5 Airtight III ((From previous pressure, 2.5 kPa (= 40−37.5)) Total: 3 points

Fig. 3.4.4 Example of check sheet (Pneumatic fender)

Check sheet of Fixed type Pneumatic fender with Panel

Location	○○ County	Date of installation	○/ ○ / ○
Name of port	○○ Port	Name of quay	-10 m Wharf No. ○○
Fender size	Pneumatic ϕ 1200×1200H-120 kPa	Fender ID	No. ○

1. Rubber body 2. Air inlet valve 3. Body attachment 4. Fender panel

Date of inspection	○ / ○ / ○					
Inspector						
Items	Inspection result				Items	Inspection result
[Deterioration mode] Degree of Airtightness maintenance Deterioration level	Det.mode	Level	Condition	Det. score	Air inlet valve (1) Damage (2) Corroded	a Deformation of valve
	Airtight	III	Within ±10 kPa	1		
	Det. level	IV	Crack on outer layer	2	Body attachment (1) Damage (2) Corroded	c. Damage at valve protector
			Total	3		
	Previous pressure 120 kPa (Temp. 15 ℃) Measured pressure 115 kPa (Temp. 10 ℃) Converted pressure 116.2 kPa				Fender panel (1) Deformation (2) Corroded	c Partial bending of steel plate a Severe and widespread corrosion
Deterioration score	3				Measurement	Replace air inlet valve Replace fender panel
Considerations when deterioration score is 3~5. If checked, replacement is recommended.	a) Age 20 years or more	☑				
	b) Mooring 10,000 hours or more	☐				
	c) Load sensitive quay structure	☐				
Measure for rubber body	Replacement No (Yes) (Date of completion:)					No (Yes) (Date of completion:)

5. Fixings 6. Supports 7. Resin pad

Items	Inspection result	Items	Inspection result	Items	Inspection result
(1) Loose (2) Bent (3) Missing (4) Cut (5) Corroded	c (One nut loose) a (One bolt missing)	(1) Bends (2) Cuts (3) Corroded	a (One shackle bend) a (Severe chain corrosion)	(1) Wear/Abrasion (2) Cut (3) Missing (4) Burn	c Wear on whole surface a 2 pads missing
Measure	Re-tighten nut Replacement for missed bolt No (Yes) (Date of comp.)	Measure	Replacement No (Yes) (Date of comp.)	Measure	Replacement of missed pad No (Yes) (Date of comp.)

8. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation		Deterioration level Deterioration score Level IV : Crack at outer layer 2 points Airtight III : Within ±10 kPa of previous pressure 1 point Pressure conversion = (101.3+120)×(273+10)/(273+15)−101.3 = 116.2 Airtight III ((From previous pressure, 3.8 kPa (=120-116.2)) Total: 3 points

Fig. 3.4.5 Example of check sheet (Fixed type pneumatic fender with panel)

3.5 Cylindrical fender

3.5.1 Method of check/diagnosis and functional evaluation for cylindrical fender

In the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis of cylindrical fenders, a field survey is conducted, and function is evaluated and recorded. The procedures for check/diagnosis and functional evaluation of cylindrical fender conform to Chapter 3.2 V-type rubber fenders. The flow of check/diagnosis and functional evaluation is shown in Fig. 3.5.1.

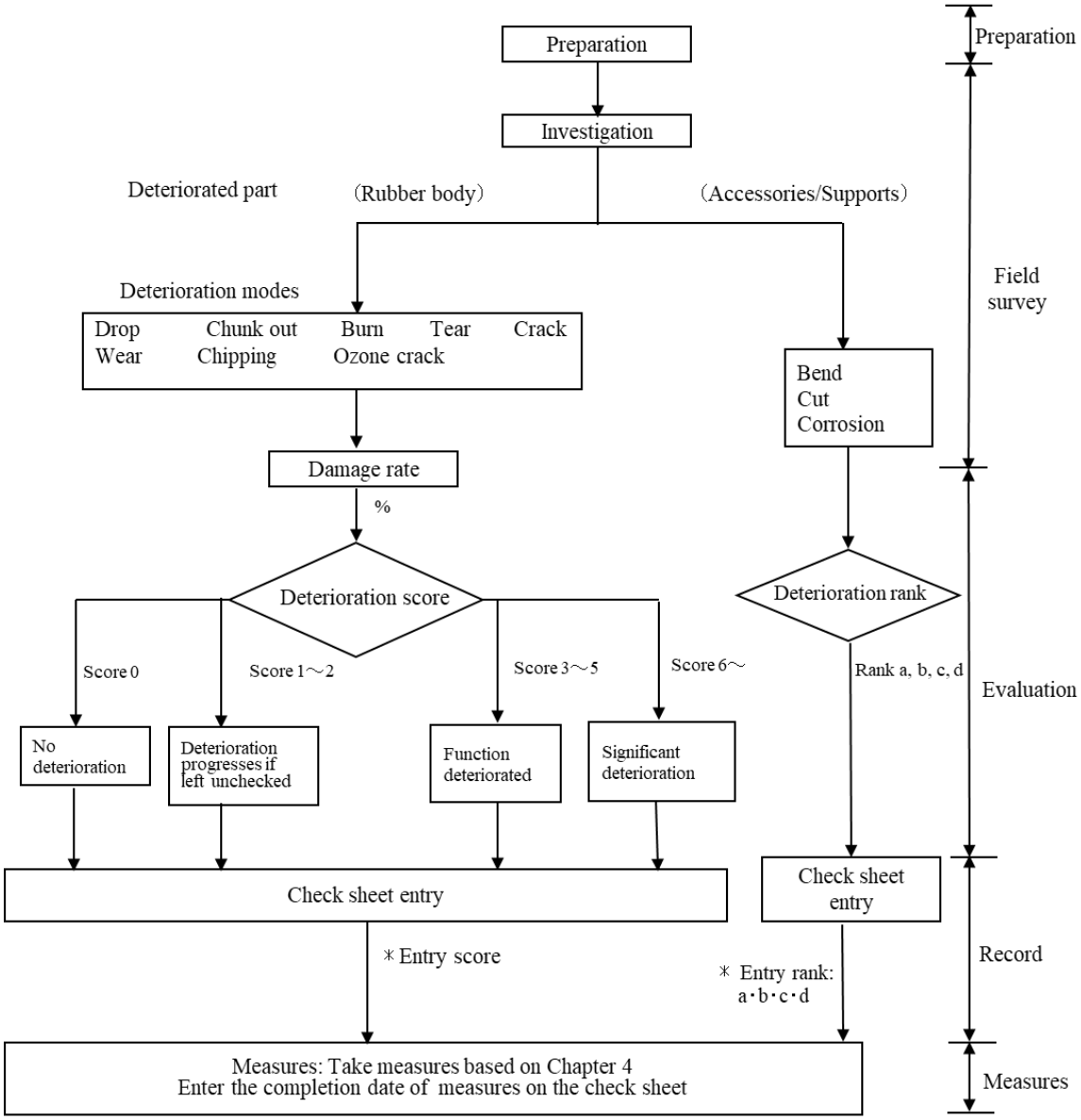


Fig. 3.5.1 Evaluation flow of check/diagnosis for cylindrical fender

3.5.2 Damage rate of cylindrical fender by field survey

The dimensions of the damaged part on the rubber body are measured, and the respective damage rates are calculated from the damaged length or damaged area.

(1) Length and area of damage

For tears, cracks, and burns, the damage rate is calculated from the damage length. The damage length is the sum of the projected lengths of damage to the longitudinal axis. This is written as damage length {L1, L2,…}.

For drops, missing rubber, chipping and wear, the damage rate is calculated from the damage area. The area of damage is the product of the length and width of the damaged part. For calculation of damage length, the following matters are considered.

a. More than one damage type

As for L_1 and L_2 shown in Fig. 3.5.2, damages occurring in the same part are calculated only when the projection length to the longitudinal axis is longer (in the example, L_1, $L_2 < L_1$). The L_2 is considered to be included in the L_1 part.

b. Damage perpendicular to the longitudinal axis of rubber fender

If cracking occurs in the direction perpendicular to the longitudinal axis of the rubber fender, as shown in L_3 in Fig. 3.5.2, it is not included in the calculation of damage length because it does not affect the deformation of the rubber body.

c. Inclined damage

As shown in the L_5 part shown in Fig. 3.5.3, if the damage is inclined, measure the projected length (L_5) to the longitudinal axis.

d. Combination of damages

- If the crack is continuous with a tear, include it in the tear and use the length of damage.
- If the missing rubber is continuous to the drop, include the drop and use it as the area of damage.
- When a tear and drop coexist, let each be the length of damage and the area of damage.
- In the case of combinations other than the above, let each be the length of damage and the area of damage.

(2) Calculation of the damage rate

The damage rate is the ratio of damaged length to the length of fender contacting face or the ratio of damaged area to fender contacting face.

a. Tears, Cracks and Burns

$$\text{Damage rate (\%)} = \frac{\text{Total damage length}}{\text{Length of fender contacting face}} \times 100 \tag{3.5.1}$$

b. Drops, Missing rubber, Chipping, Wear

$$\text{Damage rate (\%)} = \frac{\text{Total damaged area}}{\text{Area of fender contacing face}} \times 100 \tag{3.5.2}$$

1) Example of damage rate calculation

Examples of damage rate calculations for drops and tears are shown below.

a. Tears, Cracks and Burns

As shown in Fig. 3.5.2, when several damage types occur, measure the damage rate by measuring the length {L_1, L_2, L_3, L_4, L_5} of each crack. When it occurs in the same part as in the L_1 part and the L_2 part, the longer L_1 is taken. There is no damage length (L_3) in the direction perpendicular to the longitudinal axis. Therefore, L_3 is ignored. As shown in Fig. 3.5.2, when the crack (L_5) is oblique, the projection length (L_5) to the longitudinal axis is measured.

$$\text{Damage rate (\%)} = \frac{\{L_1 + L_4 + L_5\}}{L} \times 100 \tag{3.5.3}$$

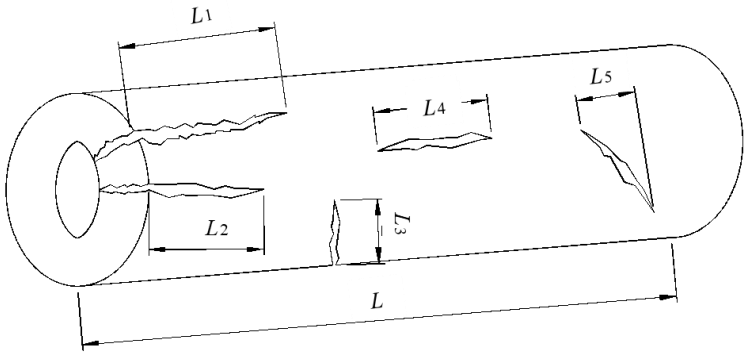


Fig. 3.5.2 Damage measurement (Cylindrical fender- Tear, Crack and Burn)

b. Drops, Missing rubber, Chipping and Wear

As shown in Fig. 3.5.3, if bulky damage occurs, measure the damage rate by measuring the length $\{L_6, L_7\}$ and width $\{W_1, W_2\}$ of each damage area.

$$\text{Damage rate (\%)} = \frac{\{L_6 \times W_1 + L_7 \times W_2\}}{L \times D} \times 100 \tag{3.5.4}$$

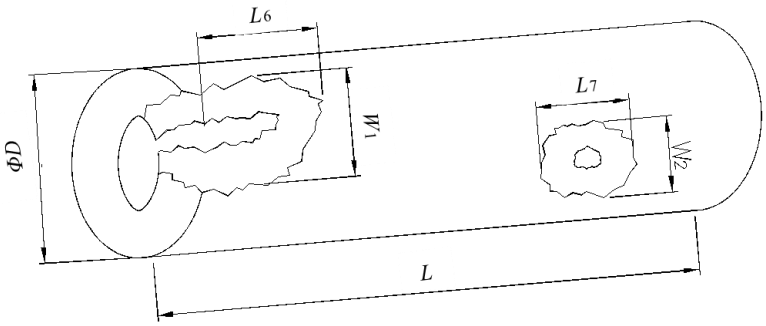


Fig. 3.5.3 Damage measurement (Cylindrical fender- Drop, Missing rubber, Chipping and Wear)

3.5.3 Functional evaluation

The functional evaluation of cylindrical fenders is divided into functional deterioration of the rubber body and deterioration rank of accessories (supports). The score of functional deterioration of the rubber body is comprehensively judged in consideration of the age of the fenders, the structure type of the quay, and the usage condition of the ship. The degree of deterioration of supports is determined to be the deterioration ranking.

Rubber body:

The score of functional deterioration of the rubber body is determined by dividing the damage rate into six stages and calculating the deterioration score that is obtained by adding the score shown for each deterioration mode and damage rate.

Accessories (Supports):

The deterioration rank of supports is determined by dividing the visual condition of the part/member into four stages.

(1) Deterioration score of rubber body

1) Method to score the deterioration

For the deterioration score of the rubber body, the score shown in Table 3.5.1 is added by each deterioration mode and damage rate. When there are two or more deterioration modes among (1) to (8), only the two larger scores are added, and the maximum ceiling is 12 points.

Table 3.5.1 Deterioration score table of rubber body (Cylindrical fender)

Deterioration mode \ Damage rate	40% or more	30~39%	20~29%	10~19%	1~9%	0%
(1) Drop (Area)	6	6	6	4	2	0
(2) Tear (Length)	6	6	6	4	2	0
(3) Missing rubber (Area)	3	2	1	0	0	0
(4) Crack (Length)	3	2	1	0	0	0
(5) Chipping (Area)	3	2	1	0	0	0
(6) Wear (Area)	1	1	1	0	0	0
(7) Burn (Length)	6	6	6	4	2	0
(8) Ozone crack	Age 20 years or more			Age less than 20 years		
	1			0		

Photo 3.5.1 Example of damage (Cylindrical fender-Missing rubber)

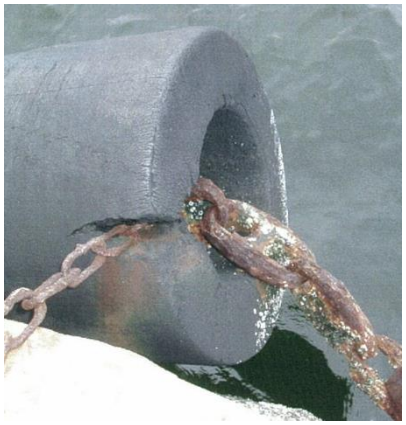


Photo 3.5.2 Example of damage (Cylindrical fender-Tear)

2) Functional evaluation

The functional evaluation of the rubber body is based on the deterioration score based on Table 3.5.2.

Table 3.5.2 Functional evaluation of rubber body (Cylindrical fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration score	Functional evaluation
6 points or more	Significant functional deterioration
3~5 points	Functional deterioration started
1~2 points	Function will deteriorate if left unchecked
0 points	No functional deterioration

For measures, see Table 4.2.1 in 4.2.1 Measures for rubber body.

(2) Deterioration rank of accessories (Supports)

The deterioration rank of supports is judged based on the condition of the part and member based on Table 3.5.3.

Table 3.5.3 Function evaluation of supports (Cylindrical fender)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Bends, cuts or progressed corrosion were found, and further use is not recommended
b	― ― ―
c	Bends or corrosion observed, but further use is possible.
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

Photo 3.5.3 Example of damage rank “c”

3.5.4 Check sheet and record

Regarding the deterioration that has occurred in the rubber body and supports, record the state of deterioration for each cylindrical fender on the check sheet. Fig. 3.5.4 shows an example of the check sheet for a cylindrical fender.

Check sheet of Cylindrical fender

Location	○○ County		Date of installation	○/ ○ / ○
Name of port	○○ Port		Name of quay	-5.0 m Wharf No. ○○
Fender size	○○ ϕ 300/ ϕ 150×1000 L		Fender ID	No.1

1. Rubber body

2. Accessories (Supports)

Date of inspection	○ / ○ / ○					
Inspector						
Items	Inspection result				Items	Inspection result
〔Det. mode〕 (1) Drop (2) Tear (3) Missing rubber (4) Crack (5) Chipping (6) Wear (7) Burn (8) Ozone crack	Det. mode	Length or area of damage	Damage rate	Det. score	(1) Bends (2) Cuts (3) Corroded	a Severe corrosion on chains
	(2)	15 cm	15%	4		
	(3)	1200 cm^2	40%	3		
			Total	7		
Deterioration score	7				Measure for accessories	Replacement No (Yes) (Date of completion:)
Considerations when deterioration score is 3~5. If checked, replacement is recommended.	a) Age 20 years or more			☐		
	b) Mooring 10,000 hours or more			☐		
	c) Load sensitive quay structure			☐		
Measure for rubber body	Replacement No (Yes) (Date of completion:)					

3. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation		Crack: Damage rate =15/100×100=15% →Deterioration score 4 points Missing rubber: Damage rate = (20×20)/(30×100)×100=40% →Deterioration score 3 points

Fig. 3.5.4 Example of check sheet (cylindrical fender)

3.6 Other rubber equipment

3.6.1 Method of check/diagnosis and functional evaluation for other rubber equipment

In the initial check and diagnosis, periodic check and diagnosis and occasional check and diagnosis of other rubber equipment, a field survey is conducted, and function is evaluated and recorded. The procedures for check/diagnosis and functional evaluation of other rubber equipment conform to Chapter 3.2 V-type rubber fenders. The flow of check/diagnosis and functional evaluation is shown in Fig. 3.6.1.

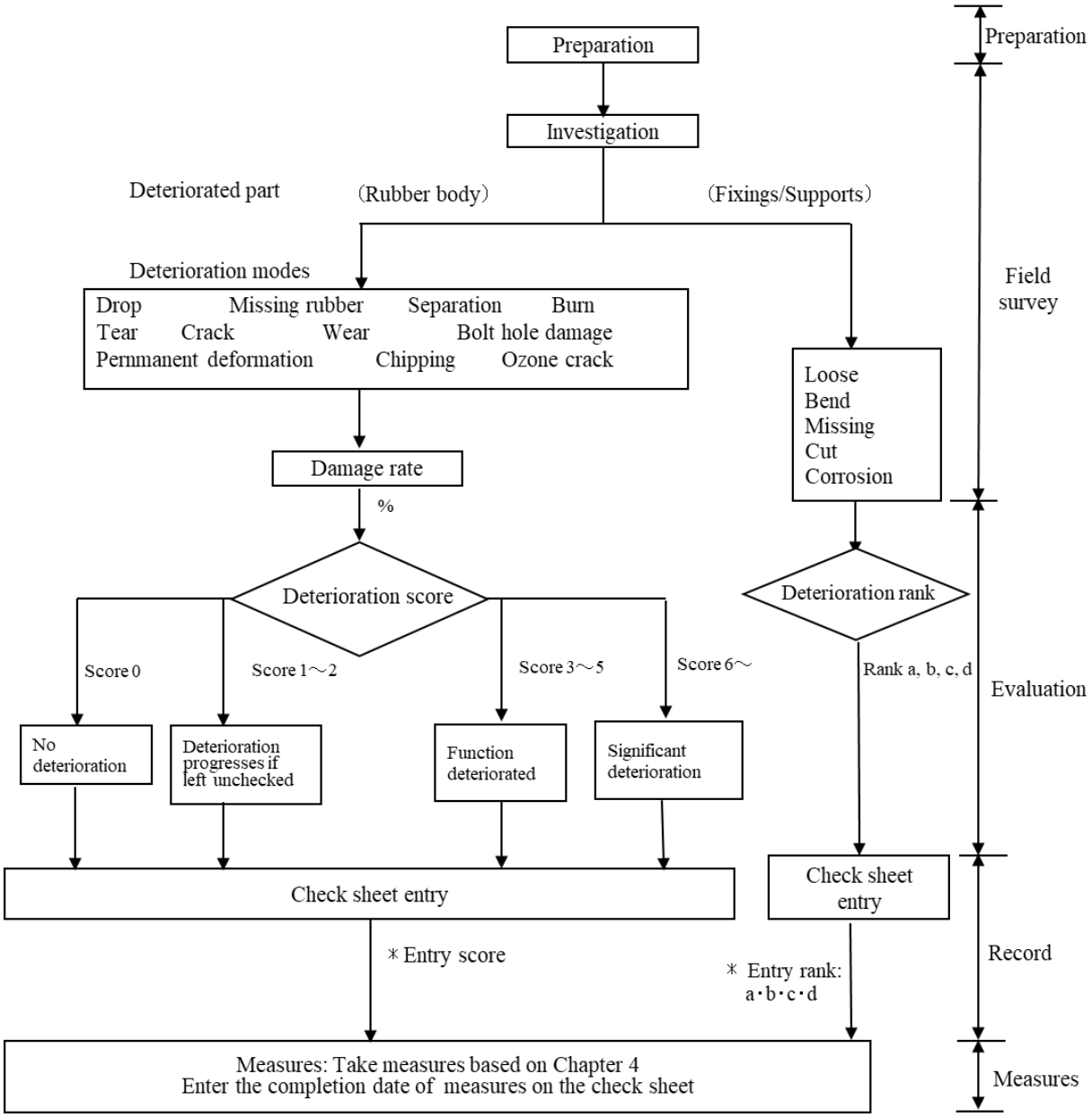


Fig. 3.6.1 Evaluation flow of check/diagnosis for other rubber equipment

3.6.2 Damage rate of other rubber equipment by field survey

The dimensions of the damaged part on the rubber body are measured, and the respective damage rates are calculated from the damaged length or damaged area. Additionally, with regard to the removed rubber equipment, it is determined whether re-installation is possible according to the state of bolt hole damage.

(1) Length and area of damage

For tears, permanent deformation, cracks, separation and burns, the damage rate is calculated from the

damage length. The damage length is the sum of the projected lengths of damage to the longitudinal axis. This is written as damage length $\{L_1, L_2, \ldots\}$.

For drops, missing rubber, chipping and wear, the damage rate is calculated from the damage area. The area of damage is the product of the length and width of the damaged part. For the calculation of damage length, the following matters are considered.

a. More than one damage area

As for L_1 and L_3 shown in Fig. 3.6.2, damages occurring in several parts are calculated only when the projection length to longitudinal axis is longer (in the example, L_3 is taken, $L_1 < L_3$ and $L_4 < L_3$). Therefore, L1 and L_4 are considered to be included in the L_3 part.

b. Damage perpendicular to the longitudinal axis of rubber equipment

If cracking occurs in the direction perpendicular to the longitudinal axis of rubber equipment, as shown in L_5 in Fig. 3.6.2, it is not included in the calculation of damage length because it does not affect the deformation of the rubber body.

c. Inclined damage

As shown in Fig. 3.6.3, if the damage is inclined (L_6), measure the projected length (L_7) to the longitudinal axis.

d. Combination of damages

- If a crack is continuous with a tear, include it in the tear and use the length of damage.
- If missing rubber is continuous to a drop, include the drop and use it as the area of damage.
- When a tear and drop coexist, let each be the length of damage and the area of damage.
- In the case of combinations other than the above, let each be the length of damage and the area of damage.

(2) Calculation of the damage rate

The damage rate is the ratio of damaged length to the length of equipment or the ratio of damaged area of equipment.

a. Tears, Permanent deformation, Cracks, Separation and Burns

$$\text{Damage rate (\%)} = \frac{\text{Damage length } \{L_1, L_2, \cdots\}}{\text{Length of rubber body } \{L\}} \times 100 \tag{3.6.1}$$

b. Drops, Missing rubber, Chipping and Wear

$$\text{Damage rate (\%)} = \frac{\text{Damage area}}{\text{Area of rubber body}} \times 100 \tag{3.6.2}$$

(3) Example of damage rate calculation

Examples of damage rate calculations for tears and drops are shown below.

a. Tears, Cracks, Permanent deformation, Separation and Burns

As shown in Fig. 3.6.2, when several damages occur, measure the damage rate by measuring the length $\{L_1, L_2, L_3, L_4, L_5\}$ of each crack. When it occurs in the same part as in the L_1 part, L_3 part and the L_4 part, the longest L_3 is taken. There is no damage length (L_5) in the direction perpendicular to the longitudinal axis. Therefore, L_5 is ignored.

$$\text{Damage rate (\%)} = \frac{\{L_2 + L_3\}}{L} \times 100 \tag{3.6.3}$$

As shown in Fig. 3.6.3, when the crack (L_6) is oblique, the projection length (L_7) to the

longitudinal axis is measured.

$$\text{Damage rate (\%)} = \frac{\{L_7\}}{L} \times 100 \tag{3.6.4}$$

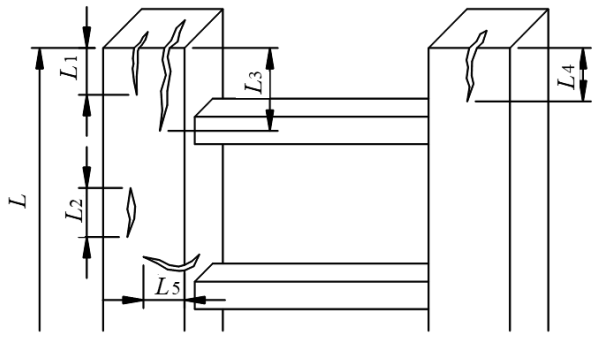


Fig. 3.6.2 Damage measurement
(Crack - Rubber ladder)

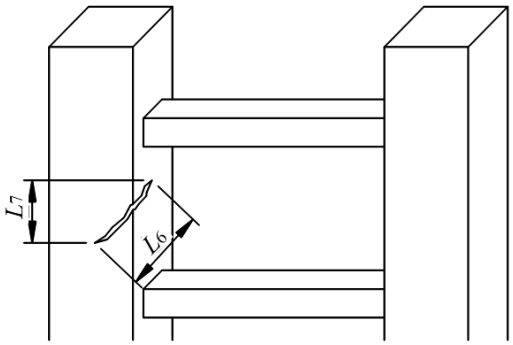


Fig. 3.6.3 Damage measurement
(Oblique crack - Rubber ladder)

b. Drops, Missing rubber, Chipping and Wear

As shown in Fig. 3.6.4, if bulky damage occurs, measure the damage rate by measuring the length $\{L_8, L_9\}$ and width $\{W_1, W_2\}$ of each damage area.

$$\text{Damage rate (\%)} = \frac{\{L_8 \times W_1 + L_9 \times W_2\}}{L \times W} \times 100 \tag{3.6.5}$$

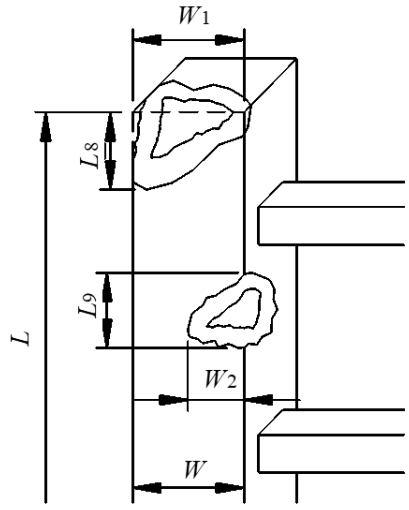


Fig. 3.6.4 Damage measurement (Drop, Missing rubber - Rubber ladder)

(4) Re-installing removed rubber equipment

If damage has occurred to the fixing holes (holes through which the fixing bolt passes through the fixing flange) of the rubber ladder, corner protector, rubber net, etc., determine whether re-installation is possible based on Table 3.2.1. Re-installation not recommended when damage occurs in one or more places. When making this judgement, you may refer to Photo 3.2.1 and Photo 3.2.2.

(5) Cuts on rubber ladder and rubber net

As shown in Figure 3.6.5, for the rubber ladder and rubber net, cutting of the step part of the rubber ladder and cutting of each grid part of the rubber net will cause fatal damage to the function, and thus each fracture

must be checked.

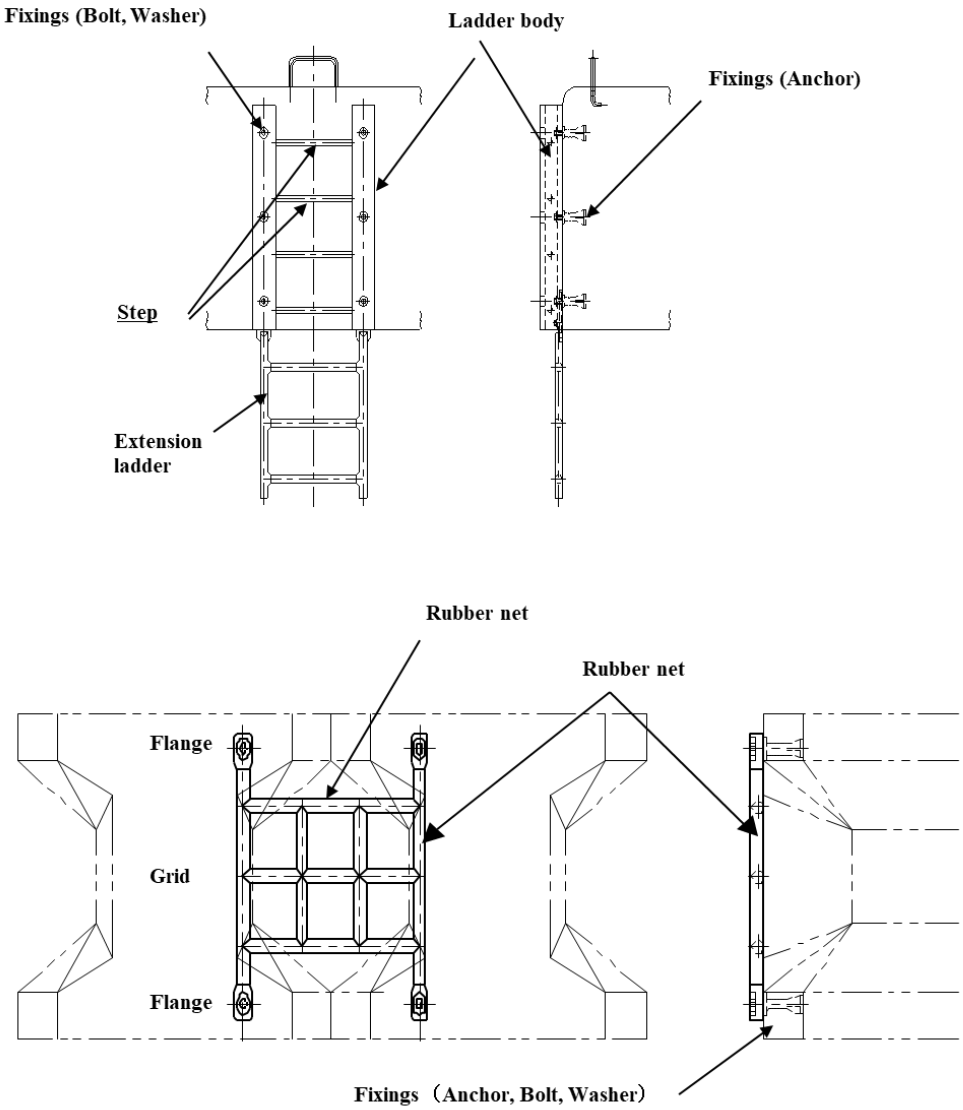


Fig. 3.6.5 Steps of rubber ladder and grid of rubber net with fixing part

3.6.3 Functional evaluation

The functional evaluation of the Other rubber equipment is divided into functional deterioration of the rubber body and deterioration rank of accessories (Fixings).

Rubber body:

The score of functional deterioration of the rubber body is determined by dividing the damage rate into six stages and calculating the deterioration score that is obtained by adding the score shown for each deterioration mode and damage rate.

Fixings:

The deterioration rank of supports is determined by dividing the visual condition of the part/member into four stages.

(1) Deterioration score of rubber body

1) Method to score the deterioration

For the deterioration score of the rubber body, the score shown in Table 3.6.1 is added by each deterioration mode and damage rate. When there are two or more deterioration modes among (1) to (12), only the two larger scores are added, while the maximum ceiling is 12 points.

Table 3.6.1 Deterioration score table of rubber body (Other rubber equipment)

Deterioration mode \ Damage rate	40% or more	30～39%	20～29%	10～19%	1～9%	0%
(1) Drop (Area)	6	6	6	4	2	0
(2) Tear (Length)	6	6	6	4	2	0
(3) Permanent deformation (Length)	6	6	6	4	2	0
(4) Missing rubber (Area)	3	2	1	0	0	0
(5) Crack (Length)	3	2	1	0	0	0
(6) Chipping (Area)	3	2	1	0	0	0
(7) Separation (Length)	3	2	1	0	0	0
(8) Wear (Area)	1	1	1	0	0	0
(9) Burn (Length)	6	6	6	4	2	0
(10) Bolt hole damage	Re-installation not recommended			Re-installable		
	6			0		
(11) Ozone crack	Age 20 years or more			Age less than 20 years		
	1			0		
(12) Cut	There is cut on step, grid or flange			No cuts		
	6			0		

Note) Cut is for rubber ladder and rubber net.

Photo 3.6.1 Example of cut on step of Rubber ladder-Deterioration score “6 point”

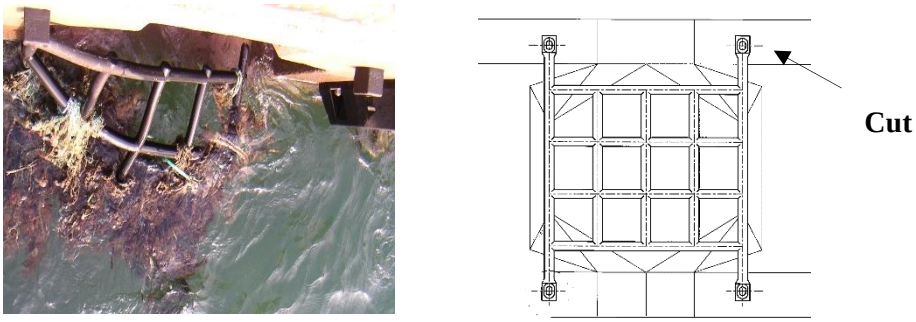


Photo 3.6.2 Example of cut on flange of Rubber net-Deterioration score“6 points”

1) Functional evaluation

Functional evaluation of the other rubber equipment is based on the deterioration score based on Table 3.6.2.

Table 3.6.2 Functional evaluation of rubber body (Other rubber equipment)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration score	Functional evaluation
6 points or more	Significant function deterioration
3~5 points	Functional deterioration started
1~2 points	Function will deteriorate if left unchecked
0 points	No functional deterioration

For measures, see Table 4.2.1 in 4.2.1 Measures for rubber body.

(2) Deterioration rank of fixings

The deterioration rank of fixings is judged based on the condition of the part and member based on Table 3.6.3.

Table 3.6.3 Functional evaluation of fixings (Other rubber equipment)
(Initial, Periodic and Occasional check/diagnosis)

Deterioration rank	Condition of part and member
a	Loose, bent, missing and/or cut
b	― ― ―
c	Corrosion observed
d	No deterioration

For measures, see Table 4.2.2 in 4.2.2 Measures for accessories.

3.6.4 Check sheet and record

Regarding the deterioration that has occurred in the rubber body and accessories, record the state of deterioration for each rubber equipment item on the check sheet. Fig. 3.6.6 shows an example of the check sheet.

Check sheet of Rubber equipment (Rubber ladder, Corner protector, Rubber net)

Location	○○ County	Date of installation	○/ ○ / ○
Name of port	○○ Port	Name of quay	-5.0 m Wharf No. ○○
Fender size	○○ 200H×1500 L	Fender ID	No.1

1. Rubber body

2. Accessories (fixings)

Date of inspection	○ / ○ / ○		
Inspector			
Items	Inspection result	Items	Inspection result

〔Det. mode〕
(1) Drop
(2) Tear
(3) Permnt. Deform.
(4) Missing rubber
(5) Crack
(6) Chipping
(7) Separation
(8) Wear
(9) Burn
(10) Bolt hole damage
(11) Ozone crack
(12) Cut

Det. mode	Length or area of damage	Damage rate	Det. score
(5)	30 cm	20%	1
(12)			6
		Total	7

(1) Loose
(2) Bent
(3) Missing
(4) Cut
(5) Corroded

a (One bolt missing)

Deterioration score	7	Measure for accessories	Bolt replacement
Considerations when deterioration score is 3~5 and age is 20 years or more, replacement is recommended.	□		
Measure for rubber body	Replacement No (Yes) (Date of completion:)		No (Yes) (Date of completion:)

3. Background information (Photo, sketch, calculation)

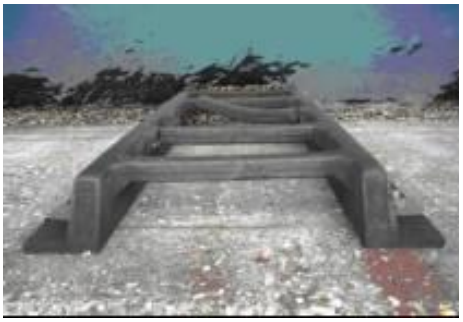
Photo or sketch of damage Process of functional evaluation		Crack: $\text{Damage rate (\%)} = \frac{\text{Length of crack } L_1}{\text{Length of rubber body } L} \times 100 = \frac{30}{150} \times 100 = 20\%$ →Deterioration score 1 points Cut: →Deterioration score 6 points

Fig. 3.6.6 Example of check sheet (Rubber ladder, Corner protector, Rubber net)

〔References〕

1) Terauchi, K., T. Koizumi, S. Yamamoto, K. Hosokawa: Deterioration Actual State and the Function Evaluation of the Rubber Fender, Technical Note of the Port and Harbour Research Institute, Ministry of Transport, Japan, No. 878, 1997 (Japanese)

2) Association for Innovative Technology on Fishing Ports and Grounds: Fender Replacement Criteria for Fishing Ports (Draft) (Functional evaluation document), 2007 (Japanese)

Chapter 4
Measures

4.1 Summary

4.1.1 General

It is generally accepted that rubber fenders eventually suffer from deterioration of function due to ageing, and post-measures against those deteriorations must be taken about once or twice during the service period of a facility. A decrease in the function of rubber fenders may cause the suspension of mooring operations at a harbour transportation facility, and it is predicted that losses due to the facility's idleness will occur. In addition, even though the visual appearance may be normal, the performance of rubber fenders decreases due to age deterioration, which may cause damage to mooring facilities and vessels. With regard to the rubber body, it is common to carry out replacement (update) as a post-measure because preventive measures are difficult or not economical. However, in the case of pneumatic fenders, checking air pressure and repair and reinforcement of the rubber body are preventive maintenance measures.

In addition to replacement (update), measures for rubber fenders include repair, replacement of position of use, and service restrictions. Appropriate measures can be taken from various viewpoints, such as deterioration status of rubber fenders, importance of facilities, and economic efficiency.

The contents of the standard measures are shown in Table 4.1.1.

Table 4.1.1 Standards and references for rubber fenders

Measure	Contents of measure
Removal	Remove when rubber fender is no longer needed.
Replacement (Update)	Replacement (update) if preventive maintenance measures such as repair are difficult or not economical. Measures such as in-service suspension may be required during the renewal period.
Repair	Repair when the performance and durability can be restored to a certain level. Generally, it is difficult to recover the function of a rubber body by repair or reinforcement, but for pneumatic fenders, there are cases where repair or reinforcement is possible, but technical knowledge is required for judgement. Measures such as in-service suspension may be required during the repair period.
Re-positioning	Replace relatively frequently used rubber fenders with less frequently used rubber fenders. During the handling period, suspension of service may be required. In addition, for partial failure, methods such as moving/rotating the position may be possible, but it is necessary to consider secondary problems.
Service restriction	Change the berthing conditions (such as berthing speed), etc., to moderate the condition in accordance with the reduced performance. These limitations require technical knowledge about the possible conditions for change. One must also ensure that they are informed to the ship handling side. Therefore, it is practical to set them as an emergency measure up to the implementation of other measures.

In addition, when deciding the repair method or the target range to take measures, it is necessary to conduct an additional survey if information is not sufficient only with the periodic inspection and diagnosis results.

4.2 Measures for rubber fender

4.2.1 Measures for rubber body

Measures for the rubber body should be implemented appropriately based on the results of functional evaluation and carried out according to the type of rubber fender and the deterioration status. In general, a rubber body is difficult to repair and reinforce, and measures are taken according to the degree of functional deterioration, as shown in Table 4.2.1.

Table 4.2.1 Measures according to deterioration score

Deterioration score	Contents of measures
6 points or more[1)]	Replacement is recommended due to significant functional deterioration
3~5 points[2)]	It is desirable to re-position rubber fenders, service restriction, or replace them as necessary, as their functions have been deteriorated.
1~2 points	If left unchecked, functional deterioration will progress, so care should be taken, such as advancing the check and diagnosis timing.
0 points	Continue the current daily check and periodic check and diagnosis because the function is maintained.

Note 1) If the deterioration score is 6 points or more, replacement is necessary, but the number of points exceeding 6 points does not necessarily indicate the priority of replacement. The priority of replacement should be determined by the facility manager taking into account the damage type, usage conditions and importance.

2) If the deterioration score is 3 to 5, there is a concern about the impact of functional deterioration, so it is desirable to replace it based on the following criteria (see Reference 2).

a. The age of the fender exceeds 20 years.

b. The total mooring time of ships exceeds 10,000 hours.

c. There is a concern that an increase in berth force or mooring force may cause structural problems (e.g., flexible quay such as dolphins).

In these measures, the damage shall be carefully checked, the cause shall be investigated, and the actual situation or the condition of use shall be considered. In addition, rubber bodies such as rubber ladders, corner protectors, rubber nets, etc., shown as other rubber equipment in Chapter 1 Section 1.2.1, take measures according to the deterioration score according to Table 4.2.1.

4.2.2 Measures for accessories

Measures for accessories must be properly implemented depending on the type of accessories and the deterioration situation.

Steel members:

If the performance of steel members such as fender panels, fixings, supports, etc. is lowered, it is necessary to take measures and select measures that satisfy the required performance. Since these steel members are generally subjected to coated corrosion protection, it is necessary to take appropriate repair in consideration of the deterioration status of corrosion protection.

Other accessories (resin pads, used tyres, rubber sleeves, etc.):

For other accessories such as resin pads, used tyres, rubber sleeves, etc., it is difficult to repair them, so they should be replaced (updated) according to the state of deterioration.

(1) Steel members

For steel members such as fender panels, fixings, supports, etc., select measures in accordance with the Manual on Corrosion Prevention and Repair for Ports and Harbour Steel Structures (2009 edition) [1]. The measures according to the degree of deterioration of steel members are shown in Table 4.2.2.

Table 4.2.2 Measures for steel members according to deterioration rank

Deterioration rank	Contents of measures
a	Implement replacement (update). In the case of loose fixing, retighten.
b	― ― ―
c	Consider such as advancing the periodic check and diagnosis timing. For fender panel, repair the coated anticorrosive work such as painting as needed.
d	Continue daily check and periodic check and diagnosis.

Note: Regardless of the deterioration of steel members, when updating the rubber body, they may be updated accordingly.

(2) Other accessories

Resin pads, used tyres and rubber sleeves used for pneumatic fenders are consumable members for preventing damage to the hull of a berthing ship or damage to the fender body. Therefore, it is desirable to take measures such as updating before the function is completely lost. The measures corresponding to the deterioration rank are shown in Table 4.2.3.

Table 4.2.3 Measures for other accessories according to deterioration rank

Deterioration rank	Contents of measures
a	Implement replacement (update).
b	― ― ―
c	Consider advancing the periodic check and diagnosis timing.
d	Continue periodic check and diagnosis.

Note: Regardless of the deterioration of other accessories, when updating the rubber body, they may be updated accordingly.

〔References〕

1) Coastal Development Institute of Technology (CDIT): Manual on Corrosion Prevention and Repair for Ports and Harbor Steel Structure, No. 35, 2009 (Japanese)

2) Terauchi, K., T. Koizumi, S. Yamamoto, K. Hosokawa: Deterioration Actual State and the Function Evaluation of the Rubber Fender, Technical Note of the Port and Harbour Research Institute, Ministry of Transport, Japan, No. 878, 1997 (Japanese)

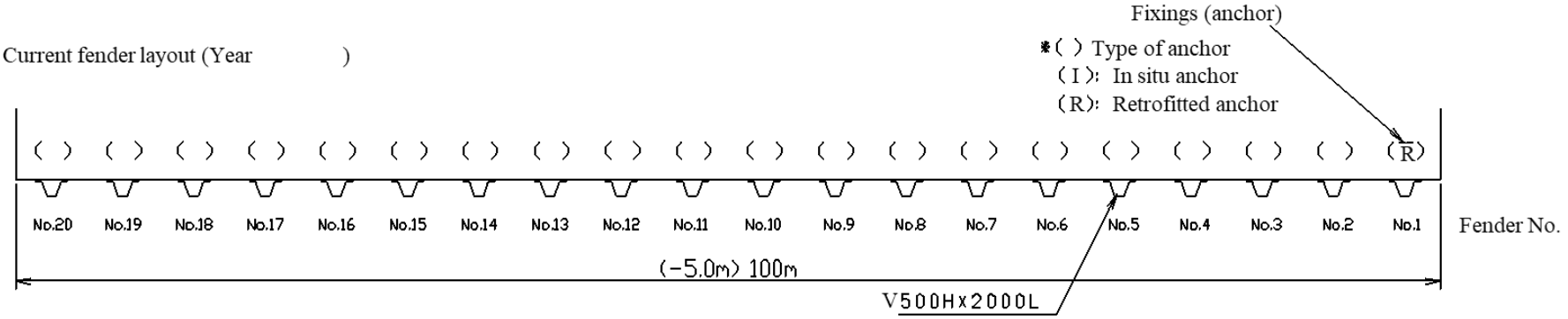
Appendix

Appendix-A Fender control chart ---------- A-1
Appendix-B Standard form of fender check and diagnosis ---------- A-2
Appendix-C Example of determining deterioration score ---------- A-8
Appendix-D Example of deterioration rank for fixing ---------- A-20

(EXAMPLE)

FENDER CONTROL SHEET ○○Port (-5.0m) 100m quay

1. Current fender layout (Year)



2. Record of fender maintenance (Started year)

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Fender No
		-		○○/○◐		○○/○○				○○/○○						-			-	Fender Replaced
		○○/○○		○○/○○		-				○○/○○						○○/○○			○○/○○	Anchor replace
		Anchor only		-		Fender only				-						Anchor only			Anchor only	Remarks

Appendix-B　Standard form of fender check and diagnosis

Check sheet of V type rubber fender

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size		Fender ID	

1. Rubber body

Date of inspection	Y　M　D			
Inspector				
Items	Inspection result			
〔Det. mode〕 (1) Drop (2) Tear (3) Permnt. Deform. (4) Missing rubber (5) Crack (6) Chipping (7) Separation (8) Wear (9) Burn (10) Bolt hole damage (11) Ozone crack	Det. Mode	Damage area length	Damage rate	Det. Score
		cm	%	
		cm	%	
			Total	
Deterioration score				
When deterioration score is 3 ～5. If checked, replacement is recommended.	a) Age 20 years or more			☐
	b) Mooring 10,000 hours or more			☐
	c) Load sensitive quay structure			☐
Measures for Rubber body	No　Yes　(Date of completion:　　)			

2. Accessories (fixings)

Items	Inspection result
(1) Loose (2) Bend (3) Missing (4) Cut (5) Corroded	
Measures for Accessories	No　Yes　(Date of completion:　　)

3. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation	

Appendix-B　Standard form of fender check and diagnosis

Check sheet of Rubber fender with Panel

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size		Fender ID	

1. Rubber body

Date of inspection	Y　M　D		
Inspector			
Items	Inspection result		
〔Det. mode〕			
(1) Tear	Det. Mode	Damage area length	Damage rate	Det. Score
(2) Crack				
(3) Permnt. Deform.				
(4) Separation		cm	%	
(5) Burn				
(6) Bolt hole damage		cm	%	
(7) Ozone crack			Total	
Deterioration score				
When deterioration score is 3 ～5. If checked, replacement is recommended.	a) Age 20 years or more		☐	
	b) Mooring 10,000 hours or more		☐	
	c) Load sensitive quay structure		☐	
Measures for Rubber body	No　Yes　(Date of completion:　　)			

2. Fender panel

Items	Inspection result
(1) Deformation	
(2) Corrosion	
Measurement for Fender panel	No　Yes　(Date of completion:　　)

3. Fixings

Items	Inspection result
(1) Loose	
(2) Bend	
(3) Missing	
(4) Cut	
(5) Corrosded	
Measures for Fixings	No　Yes (Date of completion:　　)

4. Supports

Items	Inspection result
(1) Bend	
(2) Cut	
(3) Corroded	
Measures for Supports	No　Yes (Date of completion:　　)

5. Resin pad

Items	Inspection result
(1) Wear	
(2) Abrasion	
(3) Cut	
(4) Missing	
Measures for Resin pads	No　Yes (Date of completion:　　)

6. Background information (Photo, sketch, calculation)

Photo or sketch of damage	
Process of functional evaluation	

Appendix-B　Standard form of fender check and diagnosis

Check sheet of Pneumatic fender

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size	Pneumatic Φ　×　L-　kPa	Fender ID	

1. Rubber body

Date of inspection	Y　M　D
Inspector	
Items	Inspection result

〔Det. mode〕

Degree of airtight maintenance

Deterioration level

Items	Level	Condition	Det. Score
Airtight			
Det. Level			
		Total	

Previous pressure　kPa (Temp.　℃)
Measured pressure　kPa (Temp.　℃)
Converted pressure　kPa

Deterioration score		
When deterioration score is 3 ～5. If checked, replacement is recommended.	a) Age 20 years or more	☐
	b) Mooring 10,000 hours or more	☐
	c) Load sensitive quay structure	☐
Measures for Rubber body	No　Yes (Date of completion:　)	

2. Air inlet valve,　3. Body attachment

Items	Inspection result
Air inlet valve (1) Damage (2) Corroded	
Body attachment (1) Damage (2) Corroded	
Measures	No　Yes (Date of completion:　)

4. Net

Items	Inspection result
(1) Corroded (2) Cut (3) Crack (4) Wear	
Measure	No　Yes (Date of completion:　)

5. Mooring parts

Items	Inspection result
(1) Bend (2) Cut (3) Corroded	
Measure	No　Yes (Date of completion:　)

6. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation	

Appendix-B　Standard form of fender check and diagnosis

Check sheet of Fixed type Pneumatic fender with Panel

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size	Φ　×　H-　kPa	Fender ID	

1. Rubber body　　2.Air inlet valve　3.Body attachment　4.Fender panel

Inspection date	Y　M　D		
Inspector			
Items	Inspection result	Items	Inspection result
〔Det. Mode〕 Degree of airtight maintenance Deterioration level	Items / Level / Condition / Det. Score Airtight Det. Level Total	Air inlet valve (1) Damage (2) Corroded Body attachment (1) Damage (2) Corroded	
	Previous pressure　kPa (Temp.　℃) Measured pressure　kPa (Temp.　℃) Converted pressure　kPa	Fender panel (1) Deformation (2) Corroded	
Det. Score			
When deterioration score is 3 ～5. If checked, replacement is recommended.	a) Age 20 years or more ☐ b) Mooring 10,000 hours or more ☐ c) Load sensitive quay structure ☐	Measures	
Measures for Rubber body	No　Yes　(Date of completion:　)		No　Yes　(Date of completion:　)

5. Fixings　　6. Supports　　7. Resin pad

Items	Inspection result	Items	Inspection result	Items	Inspection result
(1) Loose (2) Bend (3) Missing (4) Cut (5) Corroded		(1) Bend (2) Cut (3) Corroded		(1) Wear (2) Abrasion (3) Cut (4) Missing	
Measures for Fixings	No　Yes (Date of completion:　)	Measures for Supports	No　Yes (Date of completion:　)	Measures for Resin pads	No　Yes (Date of completion:　)

8. Background information (Photo, sketch, calculation)

Photo or sketch of damage Process of functional evaluation	

Appendix-B　Standard form of fender check and diagnosis

Check sheet of Cylindrical fender

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size	φ　×　φ　×　L	Fender ID	

1. Rubber body

Date of inspection	Y　M　D				2. Accessories (Supports)		
Inspector							
Items	Inspection result				Items		Inspection result
〔Det. mode〕							
(1) Drop	Det. Mode	Damage area length	Damage rate	Det. Score	(1)	Bend	
(2) Tear					(2)	Cut	
(3) Chunk out					(3)	Corroded	
(4) Crack		cm	%				
(5) Chipping							
(6) Wear		cm	%				
(7) Burn							
(8) Ozone crack			Total				
Deterioration score							
When deterioration score is 3 ～5. If checked, replacement is recommended.	a) Age 20 years or more			☐	Measures		
	b) Mooring 10,000 hours or more			☐			
	c) Load sensitive quay structure			☐			
Measures for Rubber body	No　Yes　(Date of completion:　)						No　Yes　(Date of completion:　)

3. Background information (Photo, sketch, calculation)

Photo or sketch of damage	
Process of functional evaluation	

Appendix-B　Standard form of fender check and diagnosis

Check sheet of Rubber equipment (Rubber ladder, Corner protector, Rubber net)

Location		Installation date	Y　M　D
Name of port		Name of quay	
Fender size	H ×　L	Fender ID	

1. Rubber body

Date of inspection	Y　M　D
Inspector	

Items	Det. Mode	Damage area length	Damage rate	Det. Score
〔Det. Mode〕				
(1) Drop				
(2) Tear				
(3) Permnt. Deform.				
(4) Missing rubber		cm	%	
(5) Crack				
(6) Chipping				
(7) Separation		cm	%	
(8) Wear				
(9) Burn				
(10) Bolt hole damage				
(11) Ozone crack			Total	
(12) Cut				

Deterioration score	
When deterioration score is 3 ～5 and age is 20 years or more, replacement is recommended.	□
Measures for Rubber body	No　Yes　(Date of completion:　)

2. Accessories (Fixings)

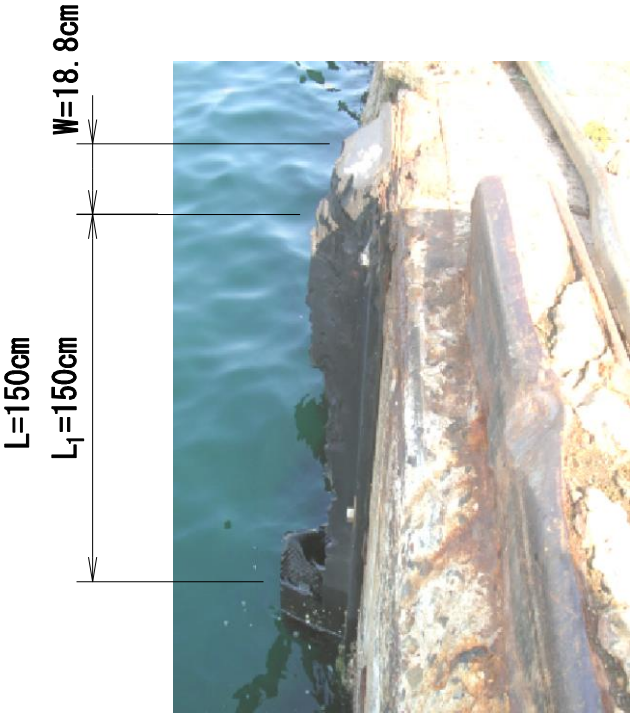
Items	Inspection result
(1) Loose	
(2) Bend	
(3) Missing	
(4) Cut	
(5) Corroded	
Measures	No　Yes　(Date of completion:　)

3. Background information (Photo, sketch, calculation)

Photo or sketch of damage	
Process of functional evaluation	

1. Example of "Drop"

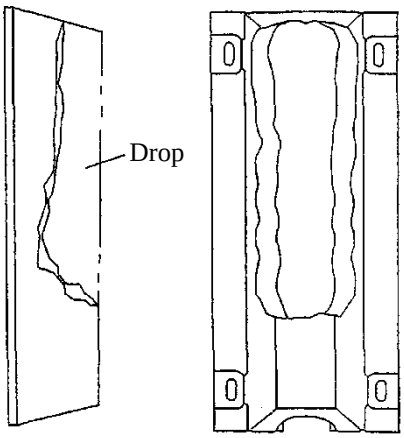
Definition : Progressed state of tear and missing rubber. There is no rubber that should be present in the facing part of rubber body or leg part, and the absence of rubber reaches hollow part

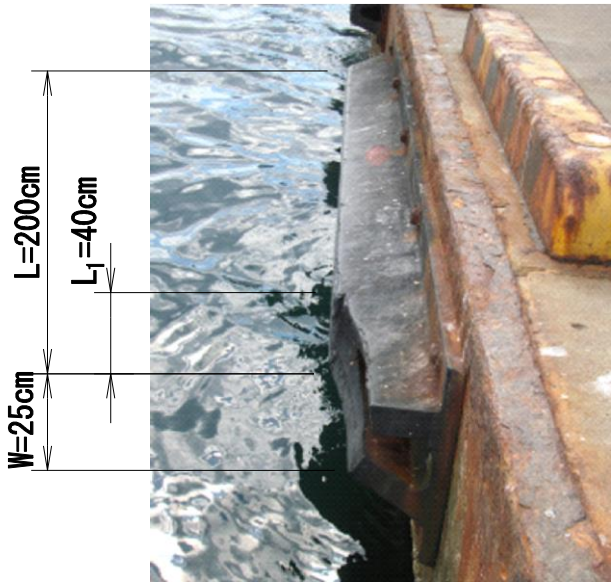


Vertically installed

（Judge）
Drop
100 %
↓
Deterioration. score
6 points

$$\frac{\text{Dropped area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 150}{18.8 \times 150} \times 100 = 100\%$$





Horizontally installed

（Judge）
Drop
20 %
↓
Deterioration. score
6 points

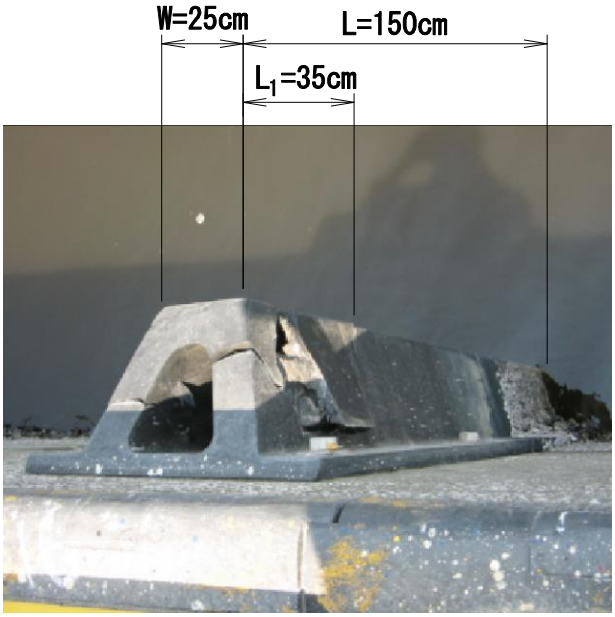
$$\frac{\text{Dropped area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{25 \times 40}{25 \times 200} \times 100 = 20\%$$

Photo C-1 Example of damage（Drop）

Appendix-C　Examples of determining deterioration score

2. Example of "Tear"

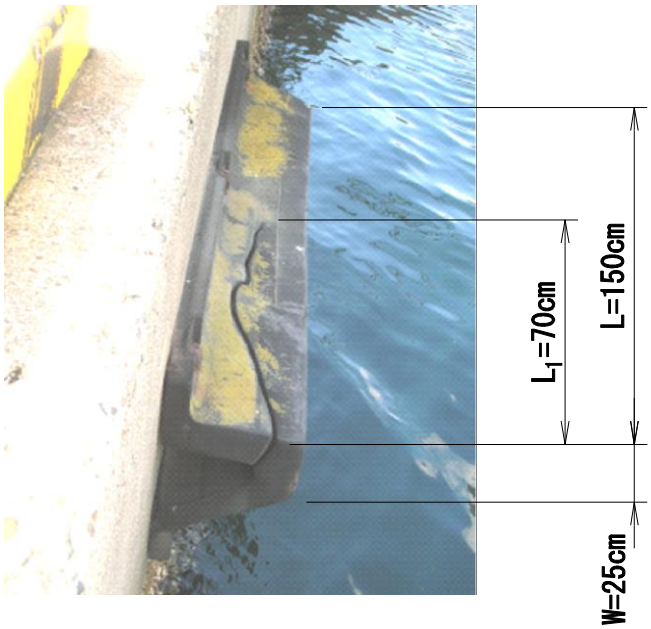
Definition : A state in which a crack generated in facing part and leg part of rubber body advances and reaches hollow part.



(Judge)
Tear
23 %
↓
Deterioration. score
6 points

$$\frac{\text{Torn length } \{L_1\}}{\text{Length of contacting face } \{L\}} = \frac{35}{150} \times 100 = 23\%$$

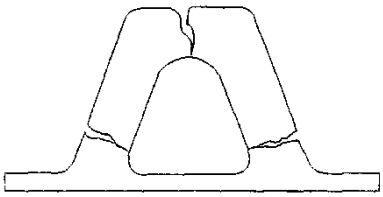
Vertically installed



(Judge)
Tear
47 %
↓
Deterioration. score
6 points

$$\frac{\text{Torn length } \{L_1\}}{\text{Length of contacting face } \{L\}} = \frac{70}{150} \times 100 = 47\%$$

Horizontally installed



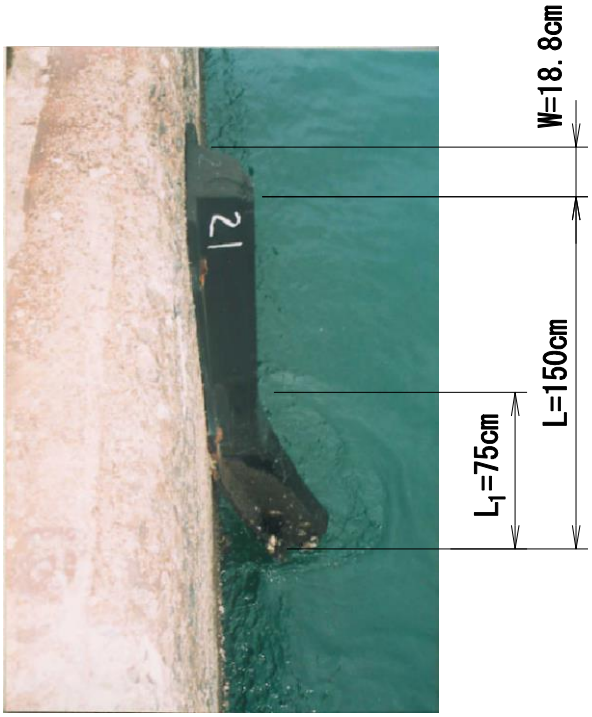
Tear

Photo C-2 Example of damage（Tear）

Appendix-C　Examples of determining deterioration score

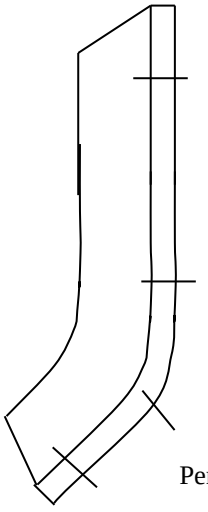
3. Example of "Permanent deformation"

Definition : A state in which the facing on rubber body, legs, and fixing flange are deformed and do not return to their original shape.



（Judge）
Permanent deformation
50 %
↓
Deterioration score
6 points

$$\frac{\text{Deformed area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 75}{18.8 \times 150} \times 100 = 50\%$$



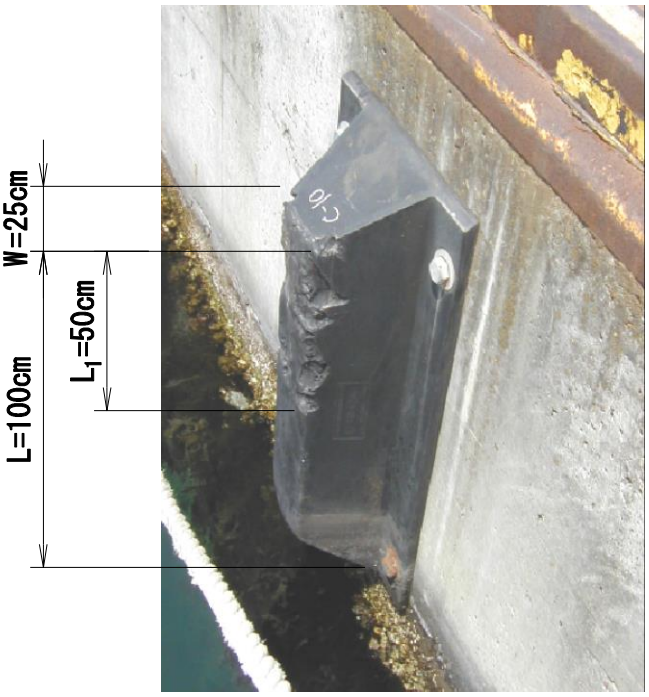
Permanent deformation

Photo C-3 Example of damage（Permanent deformation）

Appendix-C　Examples of determining deterioration score

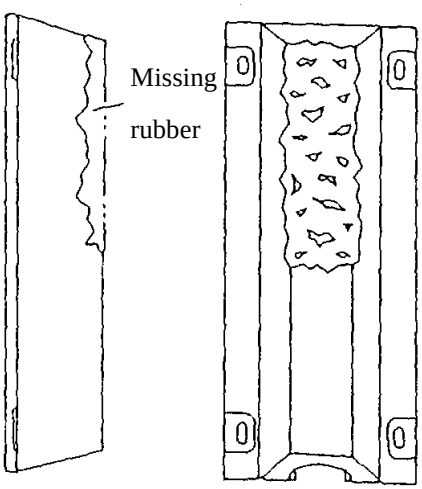
4. Example of "Missing rubber"

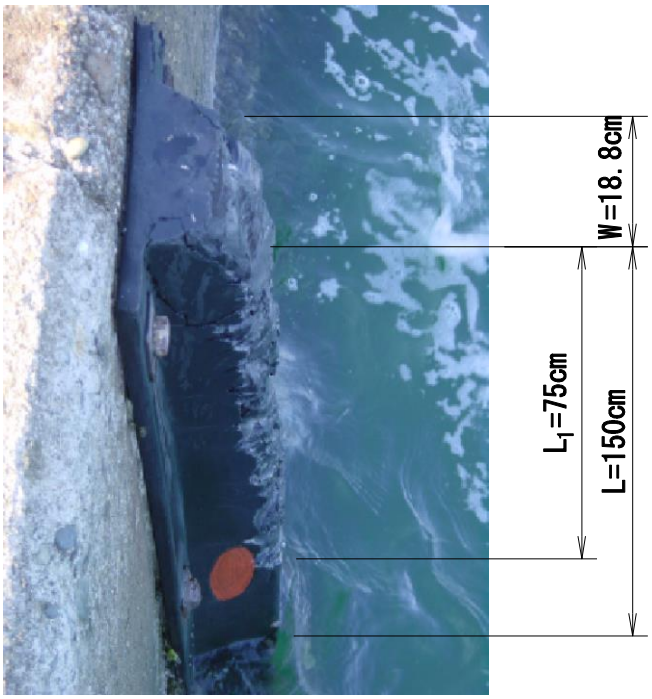
Definition: The rubber has been scraped off at contacting face of rubber body, but has not reached the hollow part.



（Judge）
Missing rubber
50 %
↓
Deterioration score
3 points

$$\frac{\text{Missing rubber area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{25 \times 50}{25 \times 100} \times 100 = 50\%$$





（Judge）
Missing rubber
50 %
↓
Deterioration score
3 points

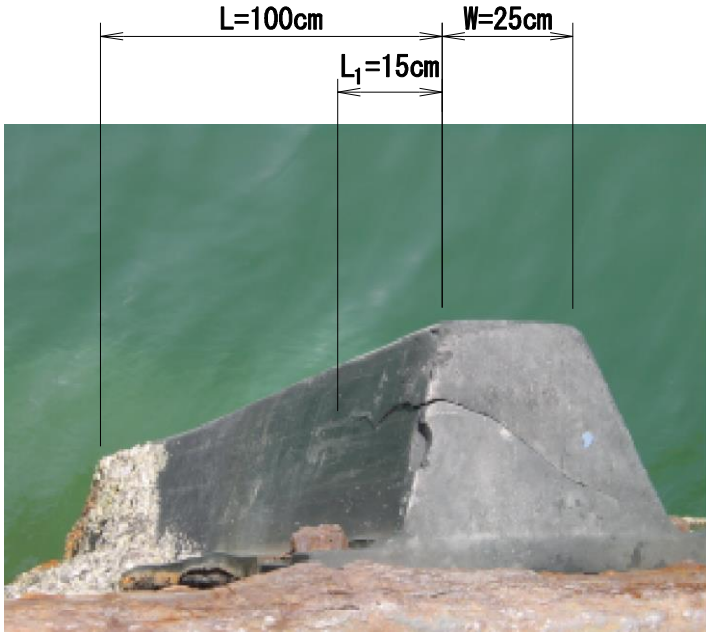
$$\frac{\text{Missing rubber area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 75}{18.8 \times 150} \times 100 = 50\%$$

Photo C-4 Example of damage（Missing rubber）

Appendix-C　Examples of determining deterioration score

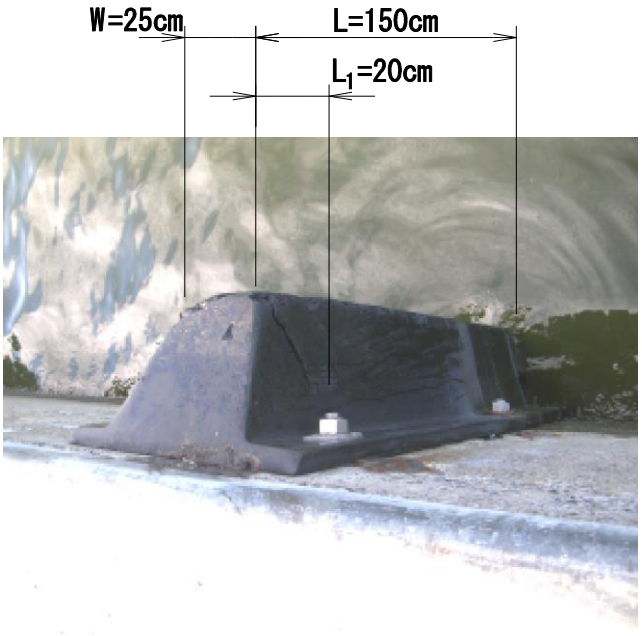
5. Example of "Crack"

Definition：The rubber surface is partially cut at contacting face and leg part of rubber body, but it has not reach the hollow part.



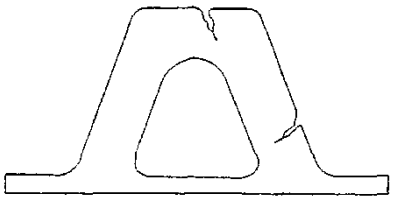
（Judge）
Crack
15 %
↓
Deterioration score
0 point

$$\frac{\text{Crack length } \{L_1\}}{\text{Length of contacting face } \{L\}} = \frac{15}{100} \times 100 = 15\%$$



（Judge）
Crack
13 %
↓
Deterioration score
0 point

$$\frac{\text{Crack length } \{L_1\}}{\text{Length of contacting face } \{L\}} = \frac{20}{150} \times 100 = 13\%$$



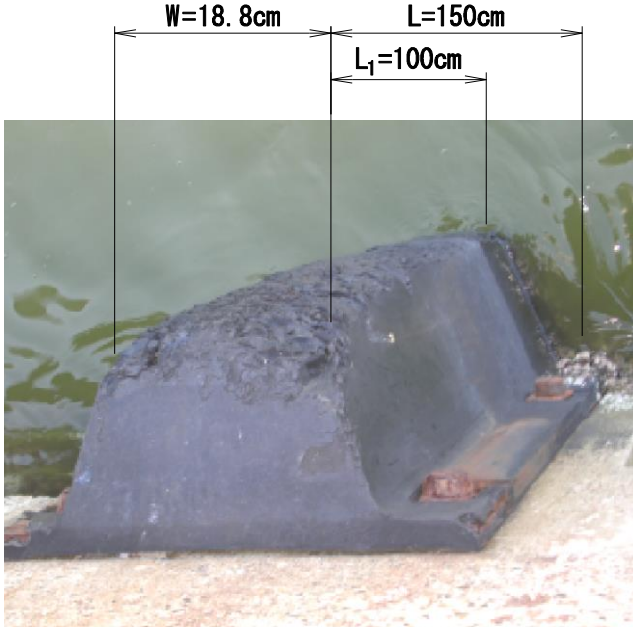
Crack

Photo C-5 Example of damage（Crack）

Appendix-C　Examples of determining deterioration score

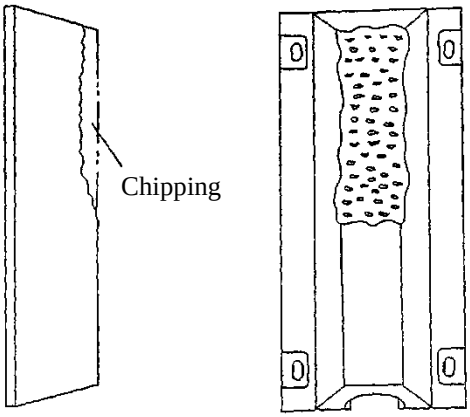
6. Example of "Chipping"

Definition: A group of small damage on surface of rubber body.



（Judge）
Chipping
67 %
↓
Deterioration score
3 points

$$\frac{\text{Chipping area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 100}{18.8 \times 150} \times 100 = 67\%$$



（Judge）
Chipping
50 %
↓
Deterioration score
3 points

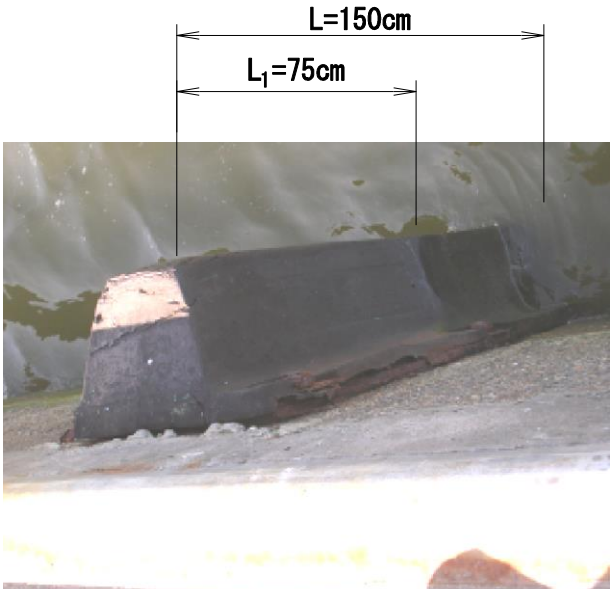
$$\frac{\text{Chipping area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 75}{18.8 \times 150} \times 100 = 50\%$$

Photo C-6 Example of damage（Chipping）

Appendix-C　Examples of determining deterioration score

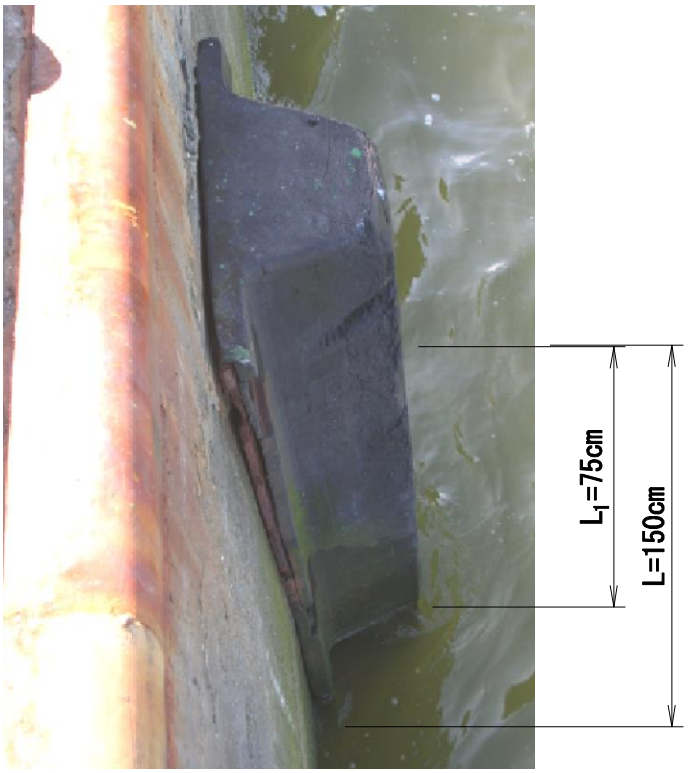
7. Example of "Separation"

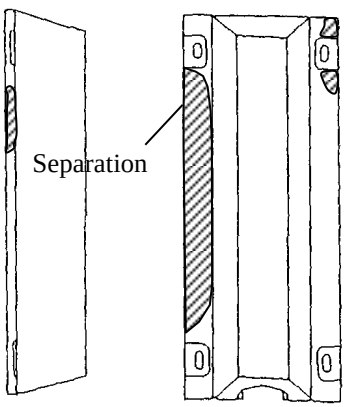
Definition：The condition that rubber of surface and side of fixing flange of rubber body is separated from embedded steel plate.



（Judge）
Separation
50 %
↓
Deterioration score
3 points

$$\frac{\text{Separated length } \{L_1\}}{\text{Length of fixing flange}\{L\}} = \frac{75}{150} \times 100 = 50\%$$





（Judge）
Separation
50 %
↓
Deterioration score
3 points

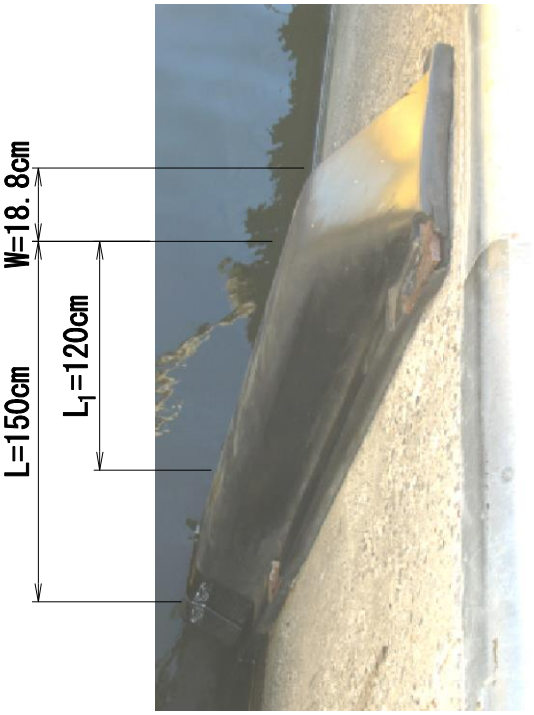
$$\frac{\text{Separated length } \{L_1\}}{\text{Length of fixing flange}\{L\}} = \frac{75}{150} \times 100 = 50\%$$

Photo C-7 Example of damage（Separation）

Appendix-C　Examples of determining deterioration score

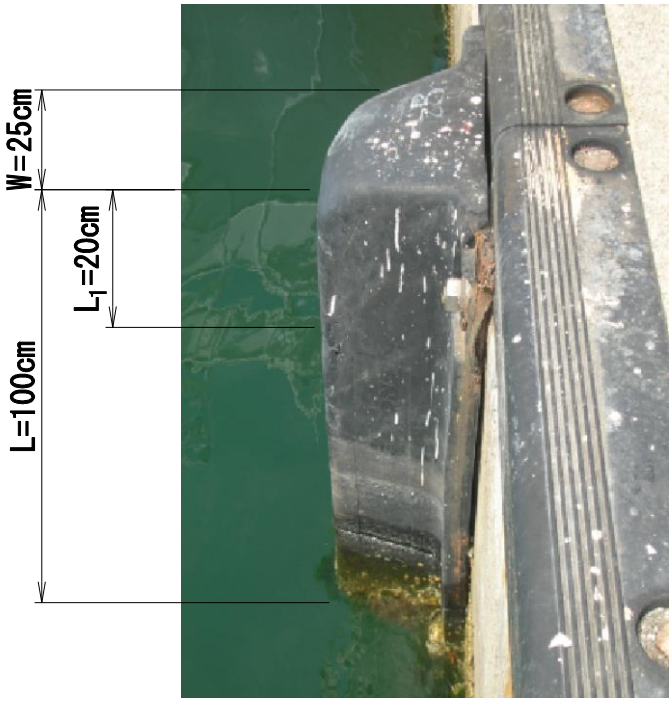
8. Example of "Wear"

Definition：The corner of contacting face of rubber body is worn out (rounded).



（Judge）
Wear
80 %
↓
Deterioration score
1 point

$$\frac{\text{Worn area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{18.8 \times 120}{18.8 \times 150} \times 100 = 80\%$$



（Judge）
Wear
20 %
↓
Deterioration score
1 point

$$\frac{\text{Worn area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{25 \times 20}{25 \times 100} \times 100 = 20\%$$

Photo C-8 Example of damage（Wear）

Appendix-C　Examples of determining deterioration score

9. Example of "Ozone crack"

Definition : A state in which an infinite number of small cracks are generated on rubber surface of contacting face, legs, hollow part, and fixing flange of rubber body.

（Judge）

Deterioration score
2 points

1 point for the age older than 20 years, plus 1 point for hazardous material (LNG berth).

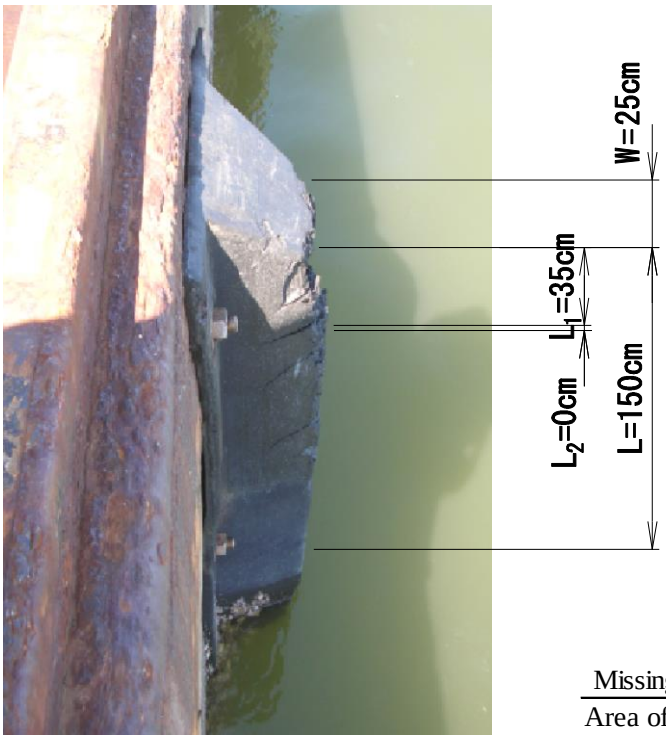
Photo C-9 Example of damage（Ozone crack）

Appendix-C　Examples of determining deterioration score

10. Example of "Combination of damages"

Definition：There is not only one deterioration mode but a combination of various deterioration modes.

1) Crack and Missing rubber



（Judge）

Crack	Missing rubber
0 %	23 %
↓	↓
Det. score	Det. score
0 point	1 point

（Add）

Total deterioration score

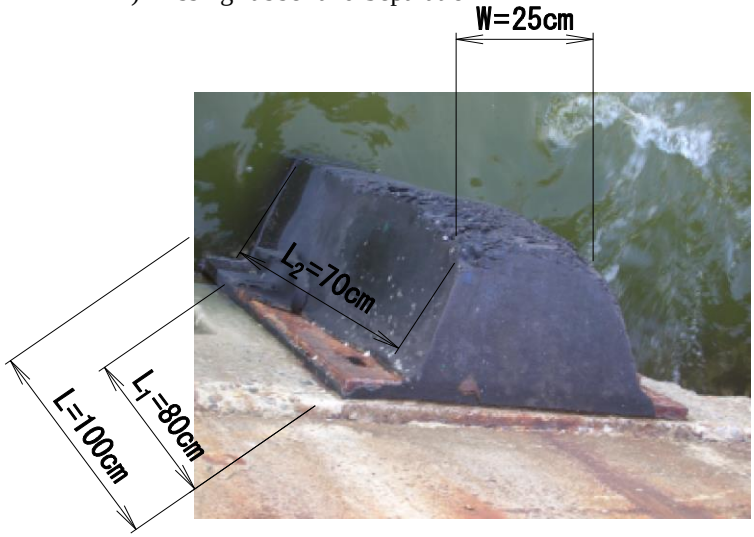
1 point

・Crack　L_2＝0 cm（perpendicular to longitudinal axis）

・Missing rubber

$$\frac{\text{Missing rubber area } \{L_1 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{25 \times 35}{25 \times 150} \times 100 = 23\%$$

2) Missing rubber and Separation



（Judge）

Missing rubber	Separation
70%	80 %
↓	↓
Det. score	Det. score
3 points	3 points

（Add）

Total deterioration score

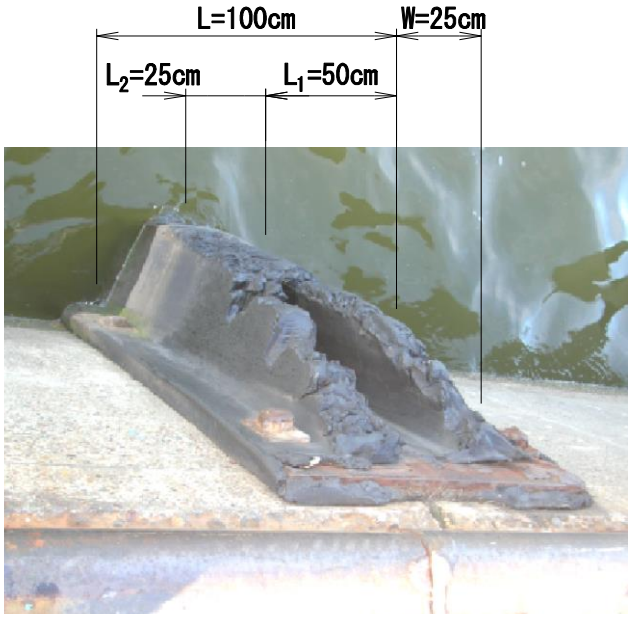
6 points

$$\frac{\text{Missing rubber area } \{L_2 \times W\}}{\text{Area of contacting face } \{L \times W\}} = \frac{25 \times 70}{25 \times 100} \times 100 = 70\%$$

$$\frac{\text{Separated length } \{L_1\}}{\text{Length of fixing flange} \{L\}} = \frac{80}{100} \times 100 = 80\%$$

Photo C-10 Example of damage（Combination of damages-1）

3) Drop and Missing rubber



（Judge）

Drop		Missing rubber
50 %		25 %
↓		↓
50 %	＋	25 %＝75 %

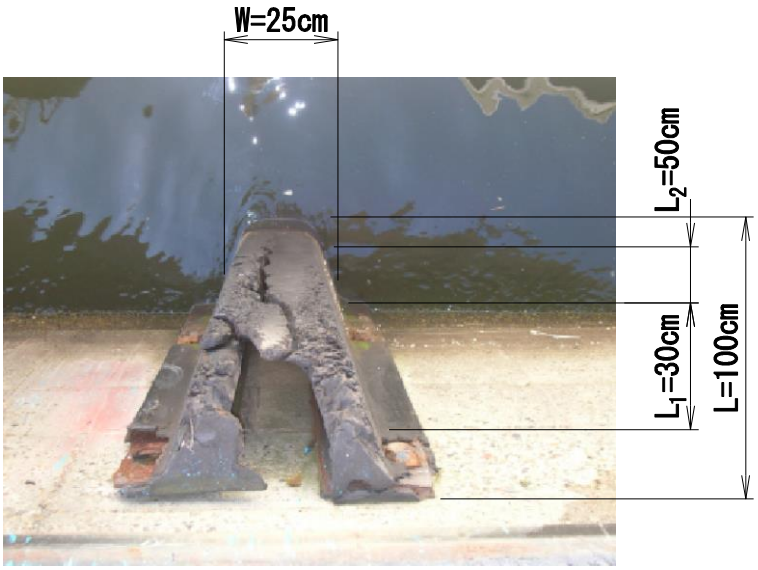
（Include in Drop)

Total deterioration score

6 points

$$\frac{\text{Dropped area } (L_1+L_2)\times W}{\text{Area of contacting face } \{L\times W\}}=\frac{(50+25)\times 25}{25\times 100}\times 100 \ =75\%$$

4) Drop and Tear



（Judge）

Drop	Tear
30 %	50 %
↓	↓
Det. score	Det. Score
6 points	6 points

（Add）

Total deterioration score

12 points

$$\frac{\text{Dropped area } \{L_1\times W\}}{\text{Area of contacting face } \{L\times W\}}=\frac{25\times 30}{25\times 100}\times 100 \ =30\%$$

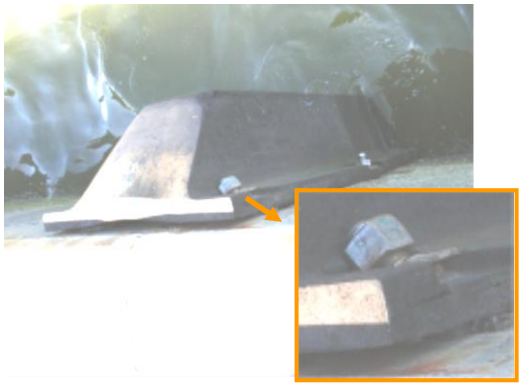
$$\frac{\text{Torn length } \{L_2\}}{\text{Length of contacting face } \{L\}}=\frac{50}{100}\times 100 \ =50\%$$

Photo C-11 Example of damage（Combination of damages-2）

Appendix-D Example of deterioration rank for fixing

① Loose of bolt (Judge) Deterioration rank a

② Bend of bolt (Judge) Deterioration rank a



③ Missing of bolt (Judge) Deterioration rank a

④ Cut of bolt (Judge) Deterioration rank a

Photo D-1 Example of deterioration rank (Fixings)

Appendix-D Example of deterioration rank for fixing

⑤ Corrosion of bolt

Progress of corrosion

a. No corrosion

(Judge) Deterioration rank d

b. Corroded (decoloration)

(Judge) Deterioration rank d

c. Corroded

Bolt decoloration

(Judge) Deterioration rank d

Washer red rust

(Judge) Deterioration rank c

d. Corroded (Red rust)

(Judge) Deterioration rank c

e. Corroded (swelling of substrate)

(Judge) Deterioration rank a

Photo D-2 Example of deterioration rank (Corrosion)

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Guidelines for Maintenance of Rubber Fender systems
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