

# **Naval Facilities Engineering Command**

200 Stovall Street  
Alexandria, Virginia 22332-2300

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# **MAINTENANCE OF FENDER SYSTEMS AND CAMELS**

**NAVFAC MO-104.1**

**SEPTEMBER 1990**



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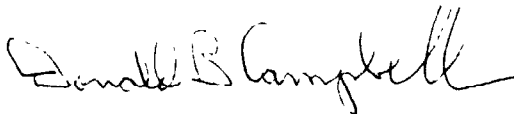
## FOREWORD

This manual provides guidance for the inspection, maintenance, and repair of waterfront fender systems and camels. It is an adjunct to the manual for **Maintenance of Waterfront Facilities, MO-104**. Specifications and standards are listed to assist the planners in selecting the appropriate materials and preventive maintenance procedures. Inspection levels, methods, planning factors, and procedures are presented. The repair procedures discussed cover preventive measures, partial replacement, and total replacement concepts for timber, concrete, steel, and synthetic components. Each procedure is developed to guide the planners in the selection of the repair technique, inspection of field work for acceptability, and planning the follow-on inspection requirements.

The standards and methods presented are intended to accomplish the inspection, maintenance, and repair in the most efficient and cost effective manner. The procedures outlined have been developed from the best technical sources available in industry and the military services.

Additional information or suggestions that will improve this manual are invited and should be submitted through appropriate channels to the Naval Facilities Engineering Command, (Attention: Code 1632), 200 Stovall Street, Alexandria, VA 22332-2300.

This publication has been reviewed in accordance with the Secretary of the Navy Instruction 5600.16A and is certified as an official publication of the Naval Facilities Engineering Command.



**D. B. CAMPBELL**  
Deputy Commander for  
Public Works

## **ABSTRACT**

This manual is a guide for inspection, maintenance, and repair of waterfront fender systems and camel structures. Introductory chapters provide a summary of responsibilities and policies, elements of maintenance planning, and overview of types of facilities. Inspection levels, methods, planning, and techniques and checklists are covered for surface inspection. Preventive maintenance and typical repair methods and techniques are described and illustrated for timber, concrete, steel, and foam-filled fenders, and timber and steel framed camels.

## CHANGE CONTROL SHEET

Document all changes, page replacements, and pen and ink alterations posted in this manual.

AMENDMENT NUMBER	AMENDMENT DATE	POST DATE	POSTED BY (LAST NAME)

## CONTENTS

	Page
<b>CHAPTER 1 INTRODUCTION.....</b>	<b>1-1</b>
1.1 GENERAL.....	1-1
1.1.1 Scope.....	1-1
1.2 MAINTENANCE STANDARDS, POLICIES, AND CRITERIA.....	1-2
1.2.1 Standards.....	1-2
1.2.2 Engineering.....	1-2
1.2.3 Related Published Material.....	1-2
1.3 MAINTENANCE PLANNING.....	1-2
1.3.1 Overall Programming and Economic Considerations....	1-2
1.3.2 Elements of the Maintenance Program.....	1-2
<b>CHAPTER 2 SELECTION OF FENDER SYSTEMS AND CAMELS.....</b>	<b>2-1</b>
2.1 FENDER COMPONENTS AND SYSTEMS.....	2-1
2.1.1 Fixed Fender Systems.....	2-1
2.1.2 Floating Fender Systems.....	2-8
2.2 CAMELS.....	2-8
2.3 SELECTING A REPLACEMENT SYSTEM.....	2-13
<b>CHAPTER 3 INSPECTION.....</b>	<b>3-1</b>
3.1 GENERAL.....	3-1
3.1.1 The Inspection Approach.....	3-1
3.1.2 Levels of Inspection.....	3-1
3.1.3 Planning for Inspection.....	3-2
3.1.4 Equipment and Tools.....	3-4
3.1.5 Documentation of Inspection.....	3-5
3.1.6 References.....	3-5
3.2 PERFORMING THE INSPECTION.....	3-6
3.3 INSPECTION OF TIMBER FENDER PILING.....	3-8
3.4 INSPECTION OF CONCRETE FENDER PILING.....	3-10
3.5 INSPECTION OF STEEL FENDER PILING.....	3-12
3.6 INSPECTION OF FOAM-FILLED FENDERS.....	3-14
3.7 INSPECTION OF TIMBER CAMELS.....	3-16
3.8 INSPECTION OF STEEL FRAMED CAMELS.....	3-18
3.9 INSPECTION OF CAMELS USED TO FENDER SUBMARINES WITH SPECIAL HULL TREATMENT.....	3-20
<b>CHAPTER 4 PREVENTIVE MAINTENANCE AND REPAIR.....</b>	<b>4-1</b>
4.1 THE MAINTENANCE AND REPAIR APPROACH.....	4-1
4.2 REFERENCES.....	4-1
4.3 WOOD AND TIMBER STRUCTURES.....	4-3
4.3.1 Preventive Maintenance For Wood And Timber.....	4-3
4.3.2 Repairs To Timber Fender Piles And Camels.....	4-6
4.4 CONCRETE STRUCTURES.....	4-14
4.4.1 Preventive Maintenance For Concrete.....	4-14
4.4.2 Repairs To Concrete Fender Piling.....	4-16

**CONTENTS (Continued)**

	Page
4.5 STEEL STRUCTURES.....	4-28
4.5.1 Preventive Maintenance For Steel.....	4-29
4.5.2 Repairs To Steel Fender Piles And Camels.....	4-31
4.6 SYNTHETIC MATERIALS.....	4-42
4.6.1 Preventive Maintenance For Synthetic Materials.....	4-42
4.6.2 Repairs To Synthetic Material Components.....	4-43
<b>REFERENCES.....</b>	<b>Reference-1</b>
<b>APPENDIX A: SPECIFICATIONS AND STANDARDS.....</b>	<b>A-1</b>
<b>GLOSSARY.....</b>	<b>Glossary-1</b>
<b>INDEX.....</b>	<b>Index-1</b>

**LIST OF FIGURES**

Figure No.	Title	Page
2-1	Wood and Timber Fender Systems.....	2-2
2-2	Steel Pile Fender System.....	2-3
2-3	Uses of Concrete Fender Piles.....	2-4
2-4	Side-Loaded and End-Loaded Rubber Fenders.....	2-5
2-5	Typical Buckling Fenders.....	2-6
2-6	Typical Fixed Pneumatic Fenders.....	2-7
2-7	Timber Pile Cluster and Concrete Bearing Panel for Foam-Filled Fenders.....	2-9
2-8	Log Camels.....	2-10
2-9	Deep Draft Submarine Separator.....	2-11
2-10	Aircraft Carrier Camel.....	2-12
3-1	Exposure Zones On Piling.....	3-4
3-2	Typical Fender Piling Inspection Report Form.....	3-7
3-3	Typical Damage to Timber Fender Pile Systems.....	3-9
3-4	Typical Damage to Concrete Fender Pile Systems.....	3-11
3-5	Typical Damage to Steel Fender Pile Systems.....	3-13
3-6	Typical Damage to Foam-Filled Fenders.....	3-15
3-7	Typical Damage to Timber Camels.....	3-17
3-8	Typical Damage to Steel Framed Submarine Camels.....	3-19
4-1	Timber Pile Jacket.....	4-5
4-2	Rubbing Strip on Timber Fender Pile.....	4-5
4-3	Repair by Splicing Timber Fender Pile.....	4-9
4-4	Replacing Damaged Fender Pile With New Timber Piling.....	4-11
4-5	Typical Repairs to a Timber Camel.....	4-13
4-6	Rub Strip on a Concrete Fender Pile.....	4-16
4-7	Timber Jacket on a Concrete Pile.....	4-16
4-8	General Steps to Concrete Repair.....	4-21
4-9	Typical Crack Repair with Epoxy Grout Injection.....	4-23
4-10	Repairs to Spalled Areas on Concrete Piling.....	4-25

**CONTENTS (Continued)****LIST OF FIGURES (Continued)**

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
4-11	Example Designs For Replacement of Concrete Fender Pile Systems.....	4-27
4-12	Coating and Cathodic Protection for Steel Fender Piles....	4-35
4-13	Installing a Concrete Cap and Face on a Steel Sheet Piling Wall.....	4-37
4-14	Example Design For Replacement of Steel Fender Piling.....	4-39
4-15	Typical Repairs to a Steel Framed Camel.....	4-41
4-16	Repair of Tear in Reinforced Foam-Filled Fender Shell.....	4-47
4-17	Repair of Reinforced Foam-Filled Fender Shell.....	4-50
4-18	Preparing Tear in Unreinforced Foam-Filled Fender Shell for Repair.....	4-52
4-19	Repair of Unreinforced Foam-Filled Fender Shell.....	4-54

**LIST OF TABLES**

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
3-1	Capability of Each Level of Inspection for Detecting Damage to Fendering Systems .....	3-3
3-2	Production Rate for Surface and Underwater Inspection of Fixed Fender Piles.....	3-3

## CHAPTER 1. INTRODUCTION

**1.1 GENERAL.** This manual is a guide for the inspection, maintenance, and repair of waterfront fender and camel structures. It is a source of reference for planning, estimating, and technical accomplishment of maintenance and repair work, and may serve as a training manual for facilities maintenance personnel. This manual is an adjunct to reference 1, MO-104, Maintenance of Waterfront Facilities.

**1.1.1 Scope.** This manual provides guidance for typical maintenance and repair of waterfront fender systems and camels to retain them in continuous readiness for use by the Fleet and in support of military marine operations. The scope of maintenance and repairs accomplished shall be governed by present and planned future use of the facilities, their anticipated life, and the cost of repair versus complete rebuilding or replacement. The manual is organized to cover:

### MAINTENANCE PLANNING AND TYPES OF FACILITIES (Chapters 1 and 2)

- Overview of the Manual, maintenance policies, and the basic elements of maintenance planning.
- Overview of typical fender components and systems and camels.

### INSPECTION (Chapter 3)

- Overview of inspection levels, methods, planning, equipment and documentation.
- Guidance and checklists for inspection of timber, concrete, steel, and foam-filled fenders.
- Guidance and checklists for inspection of timber and steel-framed camels.

### PREVENTIVE MAINTENANCE AND REPAIRS (Chapter 4)

- Preventive maintenance measures for each type of material.
- Descriptions and illustrations of repair methods and techniques for typical problems encountered with fender systems and camels.
- Guidance for material selection along with pertinent references and standards.

The inspection chapter will guide the engineer, planner, and inspector in organizing, coordinating, and performing the inspection. Individual inspection objectives, illustrations, and checklists are provided as stand-alone documents for easy identification and reproduction.

The maintenance and repair chapter is similarly organized to guide engineering and maintenance personnel in planning, organizing, and coordinating maintenance and repairs for fender systems and camel structures. Each repair

procedure is a stand-alone document, with the repair description on the left and the illustration on the right hand page. For many of the repair scenarios, problem definition and application constraints are also provided to guide the user in selecting the repair technique to match the problem to be corrected.

## **1.2 MAINTENANCE STANDARDS, POLICIES, AND CRITERIA**

**1.2.1 Standards.** The standards and criteria contained in this manual have been developed by the Navy with the concurrence and approval of the Department of Defense. Compliance with these standards is mandatory in order that the maintenance of waterfront facilities will be uniform, will adequately support the operational missions of the installations, and will permit interservice assistance and support, where possible, in the interest of efficiency and economy.

**1.2.2 Engineering.** The need for and accomplishment of major repairs and rehabilitation of existing waterfront facilities will be based on experience, judgment, and engineering evaluation. When waterfront structures are in an inactive status, the maintenance policies will be consistent with the anticipated future mission of the installation and in accordance with the inactivation plan. The services of qualified technical personnel will be used to assist in the establishment of waterfront maintenance programs. A glossary of waterfront terms is provided in the back of this manual.

**1.2.3 Related Published Material.** Reference to other published materials, which provide related or more extensive information on specific areas of inspection, maintenance, design, and construction, is made where appropriate throughout this manual.

## **1.3 MAINTENANCE PLANNING**

**1.3.1 Overall Programming and Economic Considerations.** In maintenance planning and execution, full consideration must be given to future expected use of each facility, the life expectancy of the facility, and the life cycle cost of periodic repairs versus replacement of a facility or major components. The level of maintenance and programming of major repairs should be planned in consonance with the future requirement for the facility and planned replacement. The maintenance program shall be designed to include prevention of deterioration and damage, prompt detection of deficiencies, and early accomplishment of maintenance and repairs to prevent interruptions to operations or limiting full use of a facility.

The primary goal of the maintenance program is to prevent facility deficiencies from constraining the operating forces. A well planned and executed program will keep each facility at full efficiency and minimize downtime. The Navy's principal guide for maintenance management is Naval Facilities Engineering Command (NAVFAC) MO-321 (reference 2). NAVFAC MO-104 (reference 1) provides maintenance management guidance for waterfront structures.

### **1.3.2 Elements of the Maintenance Program**

**1.3.2.1 Inspection.** Continuous, rigorous inspections are necessary for an effective maintenance program. NAVFAC MO-322 (reference 3) contains guidelines for inspection and preventive maintenance programs. The use of guides, check-off

forms, reports, and record systems is an integral part of inspection. Types of inspections typical to waterfront fender systems and camels are:

- Operator inspection consisting of examination and minor adjustment performed by port services and public works personnel on a continuous basis.
- Controlled inspection consisting of the major scheduled examination of all components and systems on a periodic basis to determine and document the condition of the fender systems and to generate major work requirements.

It is recommended that controlled inspections be made annually of all basic fender systems and camels. Additional inspections will be necessary under certain circumstances, such as severe storms, high tides, tidal waves, earthquakes, typhoons, heavy freezes, and high impact berthings. Inspections may be made from the pier, from a boat or float, or below the waterline by divers.

**1.3.2.2 Maintenance.** Maintenance is the recurrent day-to-day, periodic, or scheduled work that is required to preserve or restore a facility to such a condition that it can be effectively utilized for its designed purpose. It includes work undertaken to prevent damage to or deterioration of a facility that otherwise would be more costly to restore. The more common concerns in maintenance of fender systems and camels are:

- Painting and protective coating.
- Repair and replacement of fender components to prevent damage to ships and the pier.
- Protection of piling at the waterline.
- Patching and repair of concrete spalls and cracks.

**1.3.2.3 Repair and Reconstruction.** Repair is the restoration of a facility to such a condition that it can be effectively utilized for its designed purpose. The repair is accomplished by overhaul, reprocessing, or replacement of constituent parts or materials that have deteriorated by action of the elements or usage and have not been corrected through maintenance. Repair can be incorporated in a concurrent modernization program. The more common repair projects are:

- Replacement/reconstruction of fender systems matching existing materials.
- Replacement/reconstruction of fender systems using alternative materials and designs.
- Replacement/restoration of camels.

NAVFAC design manuals, references 4 and 5, provide guidance for design of replacement systems.

**1.3.2.4 Control of Destructive Marine Organisms** Control begins with the use of materials resistant to marine organisms when waterfront structures and other

harbor facilities are designed and constructed. The control is a continuing requirement involving all known corrective measures and providing effective countermeasures to inhibit the growth of destructive organisms in waterfront facilities. NAVFAC MO-104 (reference 1) provides more detailed descriptions of the destructive marine organisms and treatment methods.

**1.3.2.5 Documentation.** A strong maintenance management program is essential for providing adequate cost effective solutions to waterfront facilities problems. At the heart of this management program is good record keeping including the following:

- System design data including properties of materials used in the fender system or camel, and original load calculations.
- Environmental data including current, wind, and tidal ranges.
- Berthing data including type and class of ships, nesting requirements, and frequency of arrivals and departures.
- Maintenance and repair history for the facility including type, extent, and frequency of damage.

With these records, the planner will be able to analyze the type, extent, and frequency of damage; confirm or update berthing and mooring force calculations in accordance with reference 4; and select the alternatives to be considered in the maintenance and repair decision.

## CHAPTER 2. SELECTION OF FENDER SYSTEMS AND CAMELS

The question of repair versus replacement is a continuing decision in the management of fender system and camel maintenance. As long as the component parts can be adequately repaired without excessive cost, frequency of repair and berth downtime, the existing fender system or camel should be kept in use. A prime consideration, also, is that repair does not decrease the effectiveness and capacity of the system. When replacement becomes necessary or cost effective, there is an opportunity to improve existing berthing facilities by replacing obsolete and high maintenance systems. The basic considerations in selecting a replacement fender system are:

- Compatibility with the pier/wharf configuration.
- Effectiveness in protecting the ship and pier under local berthing and environmental conditions.
- Initial and life cycle costs.
- Life expectancy.
- Pier out-of-service time required for installation.
- Fleet acceptance.

This chapter summarizes the major types of fenders and camels, and provides guidance for selecting a replacement type. Additional information and guidance may be found in Military Handbook MIL-HDBK-1025/1, Piers and Wharves (reference 4), on types of fender systems, evaluation of alternatives, and design.

### 2.1 FENDER COMPONENTS AND SYSTEMS

#### 2.1.1 Fixed Fender Systems.

**a. Fender Pile Systems.** This type of system has been the conventional type on Navy piers. Over the years, timber pile systems have been used most frequently and steel fender piles less often. Precast, prestressed concrete fender piles are beginning to be utilized. The fender piles usually have a chock and wale system and may be used with rubber fender units. Figures 2-1, 2-2 and 2-3 show systems using timber, steel, and concrete piles. Fender pile systems are also utilized in combination with other types of systems, such as floating fender stations.

**b. Directly-Mounted Fender Units.** A variety of commercial fendering products is available, most of which are designed for direct mounting on the pier or wharf face. Most of these units are applicable for a narrow size range of ships and a small tidal range. The more frequently used types are shown in figures 2-4, 2-5, and 2-6:

- End-loaded rubber fenders
- Side-loaded rubber fenders
- Fixed pneumatic fenders
- Rubber shear fenders
- Buckling fenders

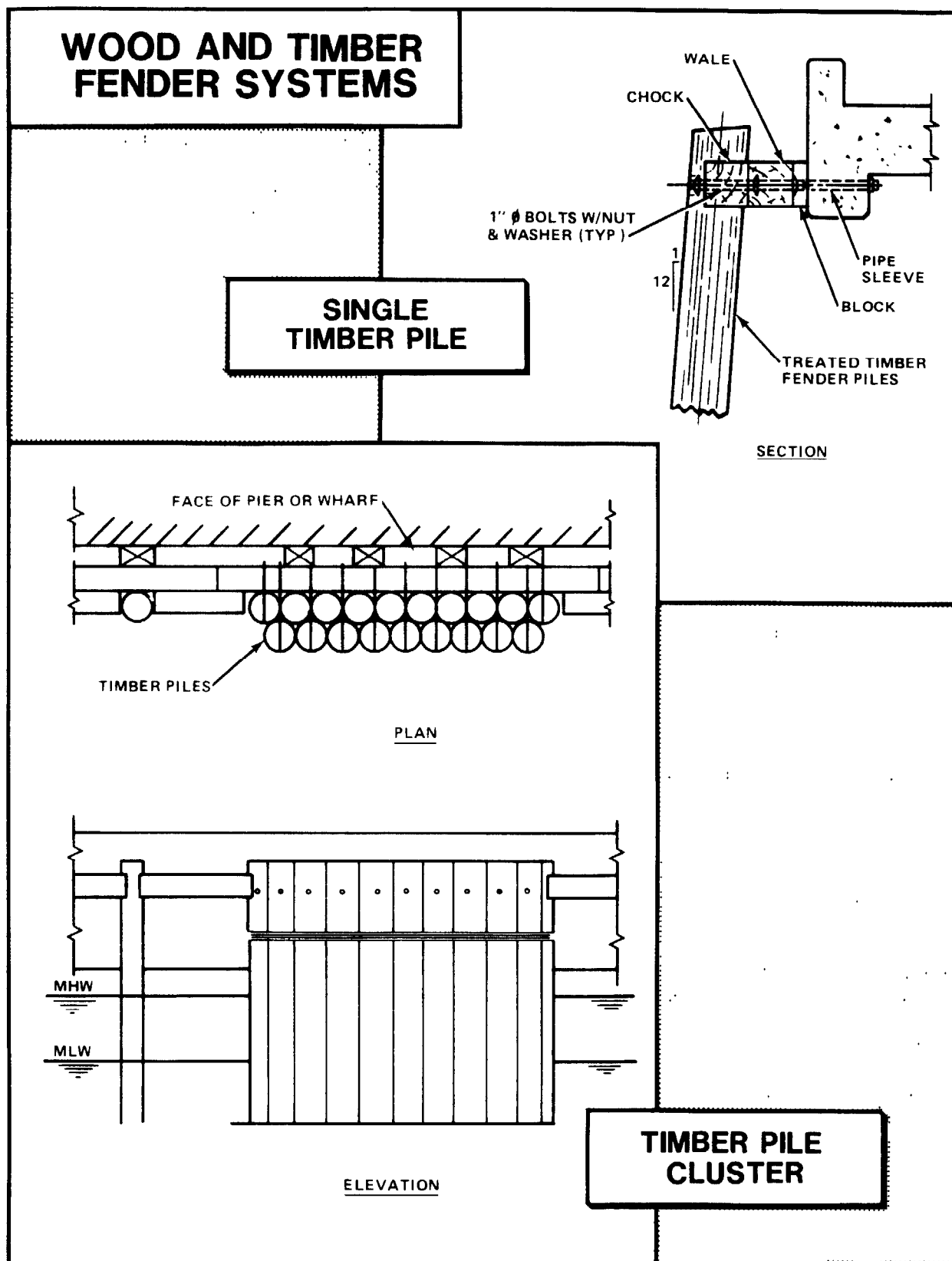


Figure 2-1. Wood and Timber Fender Systems.

# STEEL FENDER SYSTEM

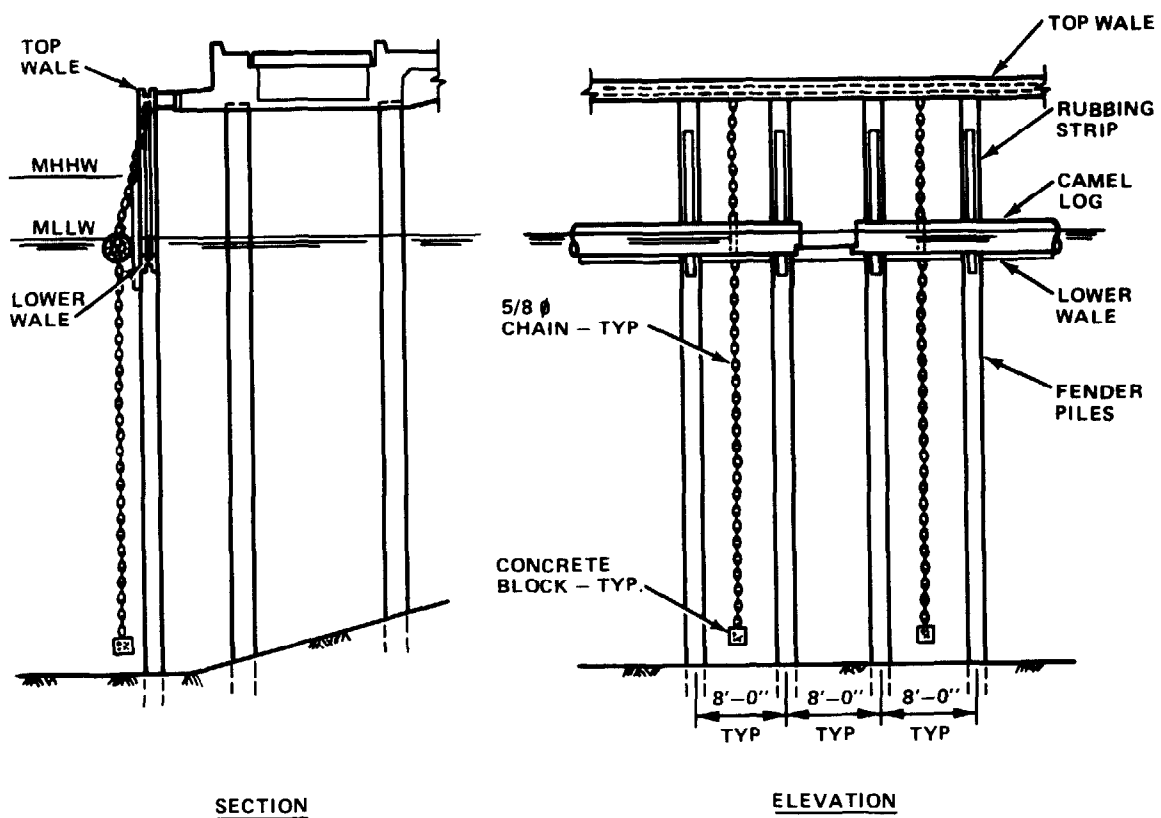


Figure 2-2. Steel Pile Fender System.

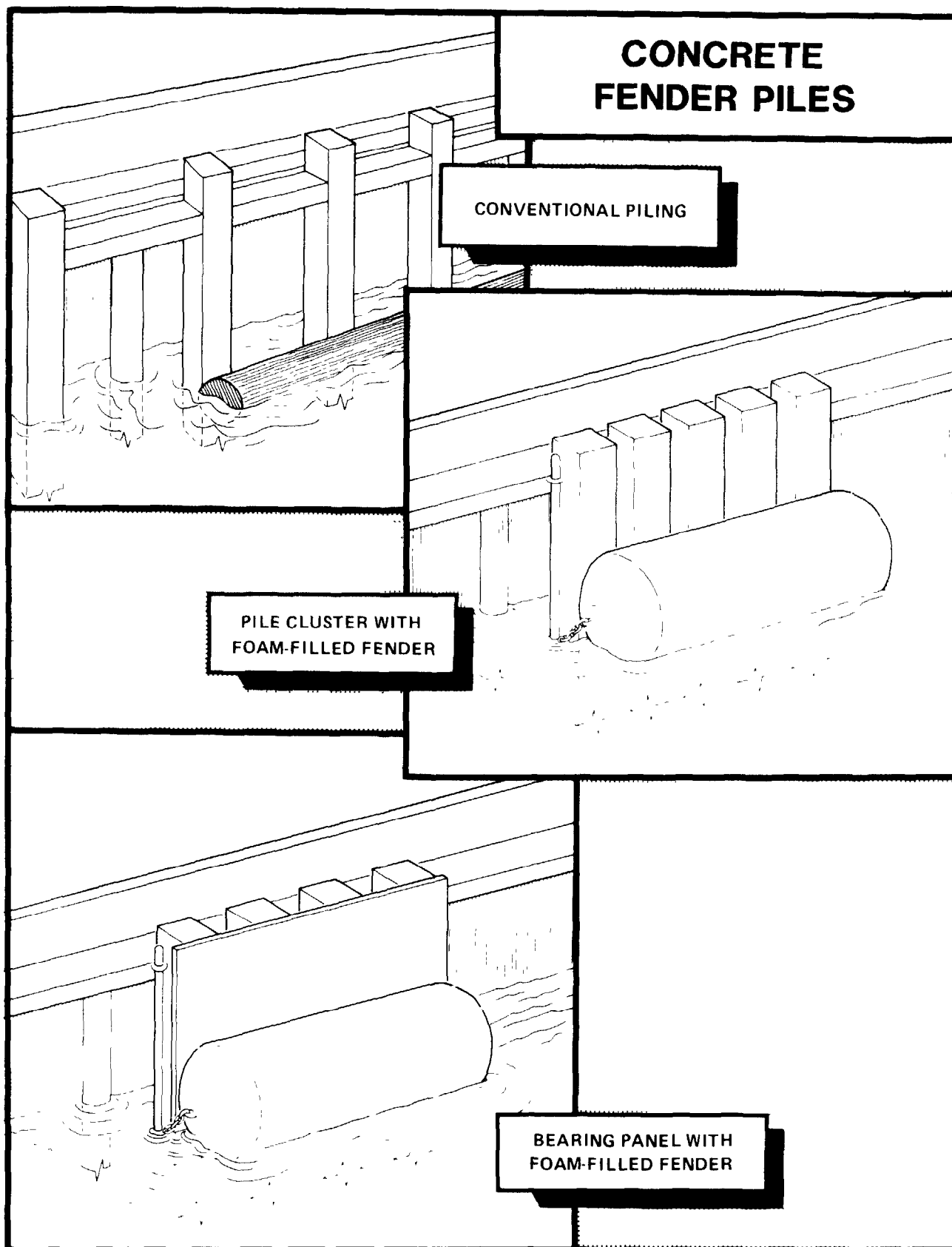


Figure 2-3. Uses of Concrete Fender Piles.

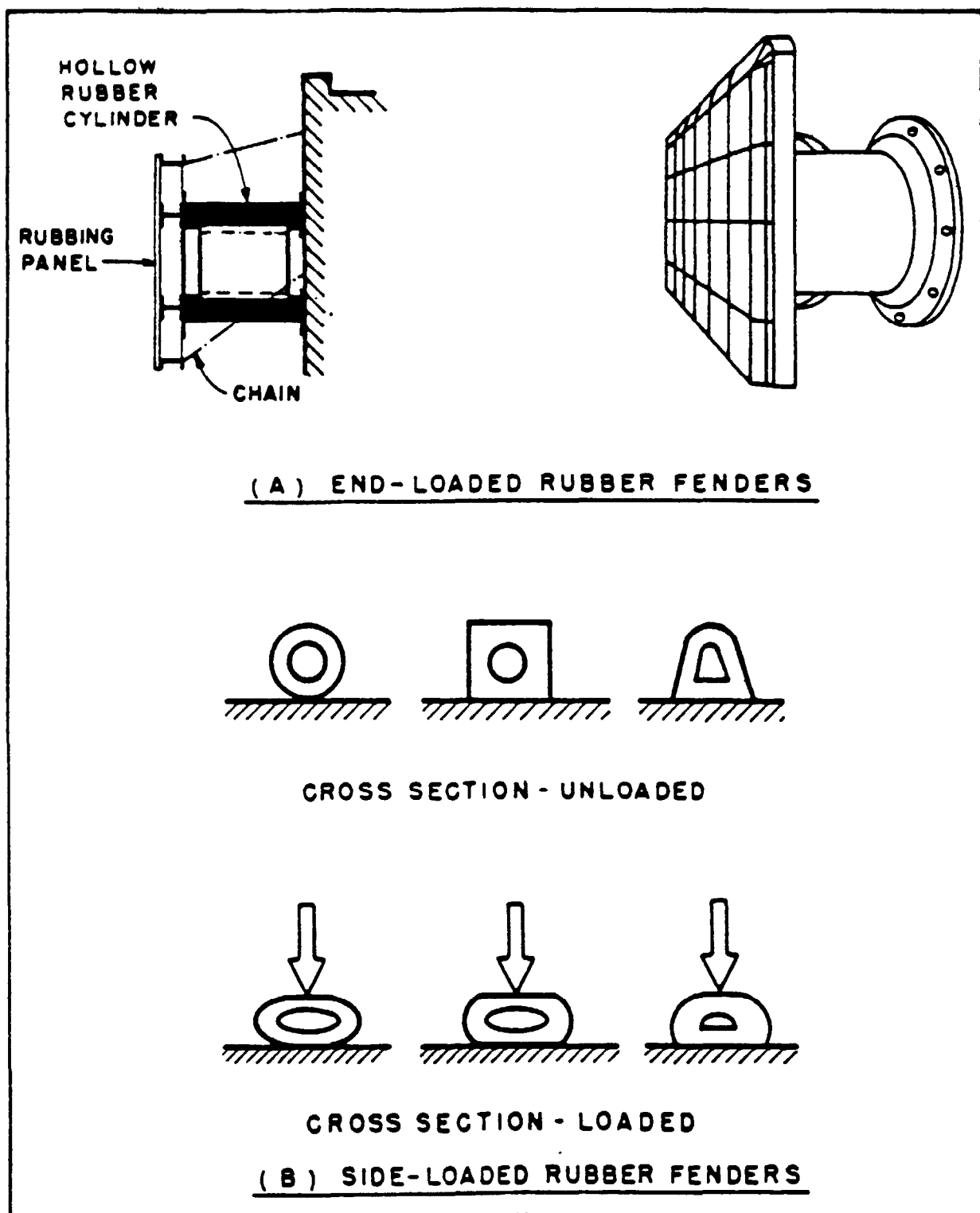
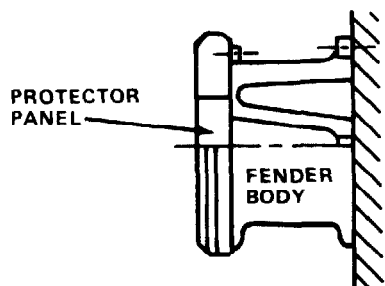
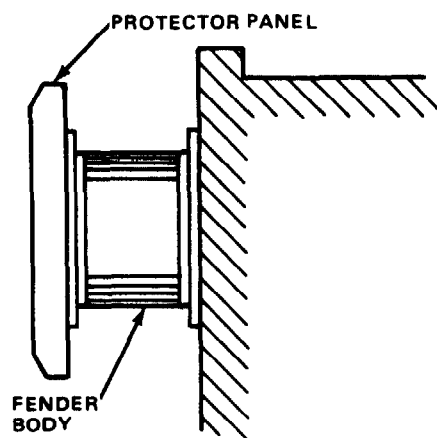


Figure 2-4. Side-Loaded and End-Loaded Rubber Fenders.

# BUCKLING FENDER

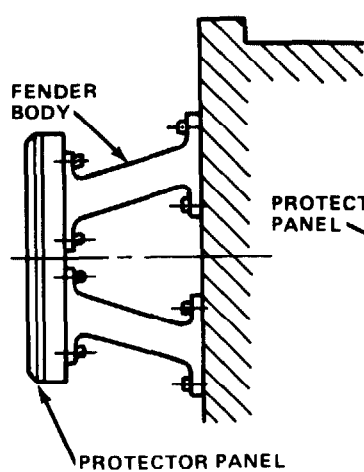


CIRCLE TYPE

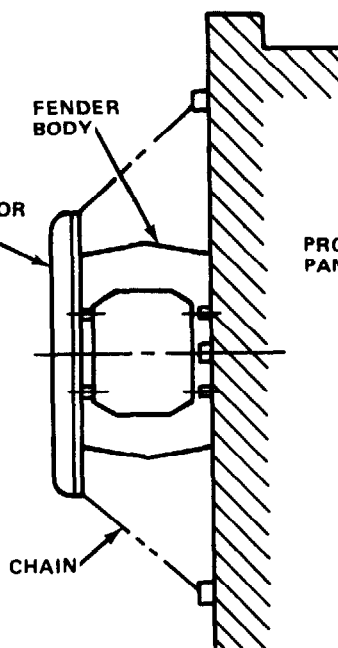


CELL TYPE

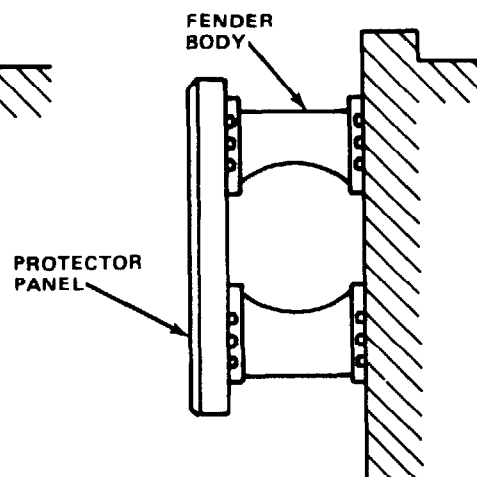
## (A) CIRCULAR SHAPE



PI TYPE



HEXAGON TYPE



F - TYPE

## (B) LONGITUDINAL SHAPE

Figure 2-5. Typical Buckling Fenders.

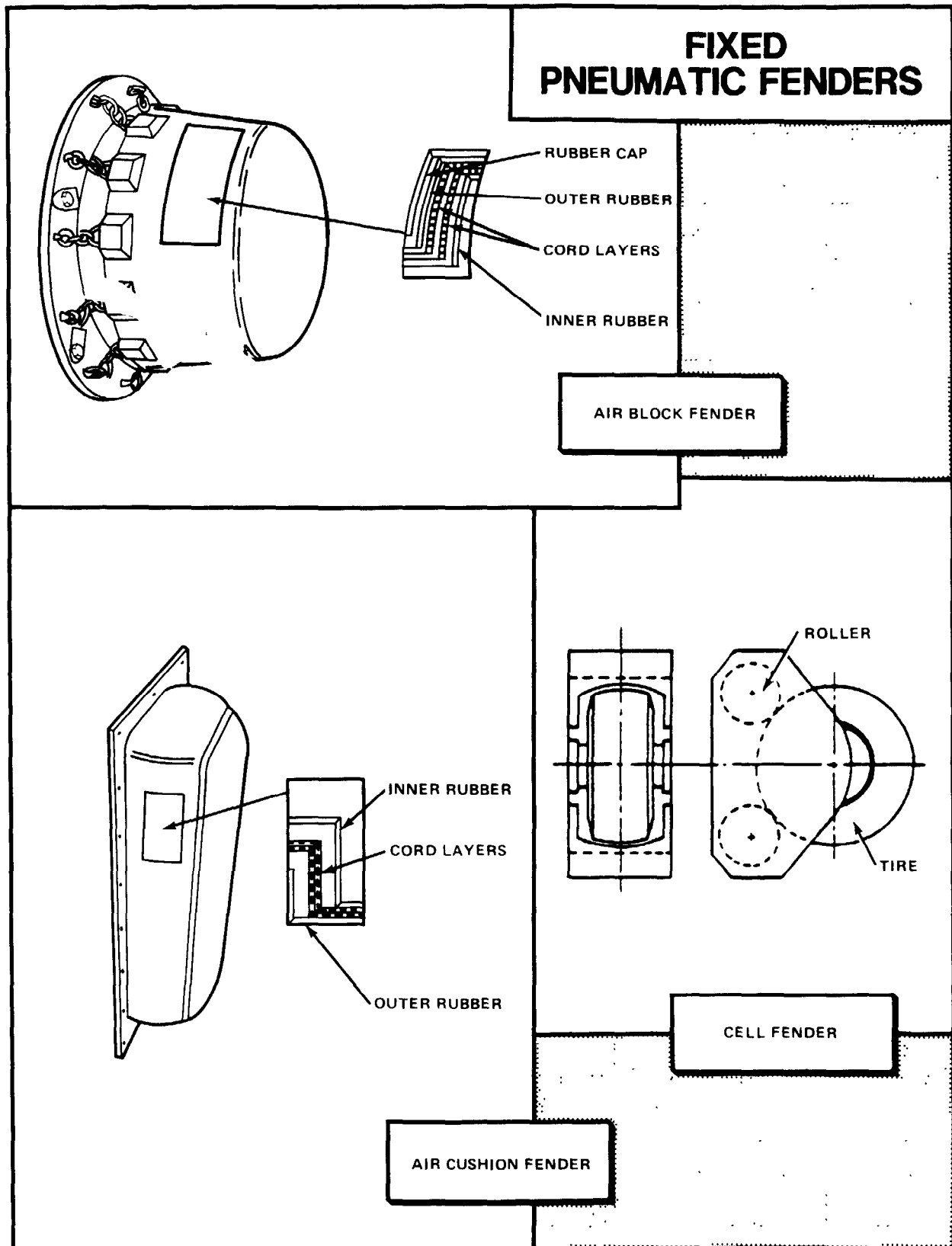


Figure 2-6. Typical Fixed Pneumatic Fenders.

**2.1.2 Floating Fender Systems.** Foam-filled and pneumatic fenders are used in various types of fendering configurations. Foam-filled fenders are becoming more common in Navy ports both in replacement systems and on new piers and wharves. Figures 2-3 and 2-7 illustrate typical installations.

**a. Foam-Filled Fenders.** The foam-filled fender consists of an elastomer shell filled with closed-cell polyethylene foam. As a load is initially applied to the external shell, it begins to deform, transferring the load to the foam filling. There are two types of foam fenders: net and netless. The netless fender has a built-in end fitting for attaching the fender, while the net fender has an external rigging consisting of a chain and tire net. The netless fenders have thicker urethane skins and tend to cost more than the net fenders. However, the greater hull marking caused by the net fender due to the soft rubber of the tires, and maintenance and replacement of the chain and tire net, make the netless fender the preferred choice. Early concerns were related to possible skin puncture and tears of the netless fender due to hull protrusions. Such problems have not materialized with either the unreinforced cast or spray reinforced style fender.

In selecting a foam fender for a particular application, consideration should be given to energy absorption requirements, bearing surface size, allowable ship hull pressure, stand-off distance, ease of repair, and standard manufactured sizes. For many Navy applications, the 7-foot diameter by 14-foot long fender is well suited. Because foam fenders do not bridge the ship's stringers, hull pressure is more of a consideration.

**b. Pneumatic Fenders** Pneumatic floating fenders employ the elastic behavior of air under compression to absorb energy. As a load is applied, the shell is deformed and the entrapped air is compressed. The rubber shell of the pneumatic fender contains the air, conforms to the surface of the vessel hull and berthing structure, and resists abrasion and tensile stresses that result during normal operation. Medium and large units are equipped with relief valves. Pneumatic fenders are currently being used by the Navy as camels between nested ships. With proper sizing and the provision of a bearing surface, they also can be used for pier to ship fendering.

**2.2 CAMELS.** The basic types of camels are as follows:

**a. Log Camels.** Single logs, 18 inches in diameter and larger, are chained to the pier or fender system, float with the tide, and provide essentially a rubbing surface for the ship. A built-up log camel may be constructed of several logs tied together. See figure 2-8.

**b. Timber Camels.** These consist of several large timbers connected together by struts and cross braces to form a large crib. Foam flotation units may be inserted between the timbers for a higher freeboard. Wear causes bolt heads to become exposed and cause damage to hulls.

**c. Steel Pontoon Camels and Separators.** These are made of cubical or cylindrical steel pontoons connected by structural framing. Steel barges with fendering are also used as camels.

Timber and steel framed camels may be combination types with various configurations of flotation units. Figure 2-9 shows a typical submarine separator and figure 2-10 one type of aircraft carrier camel.

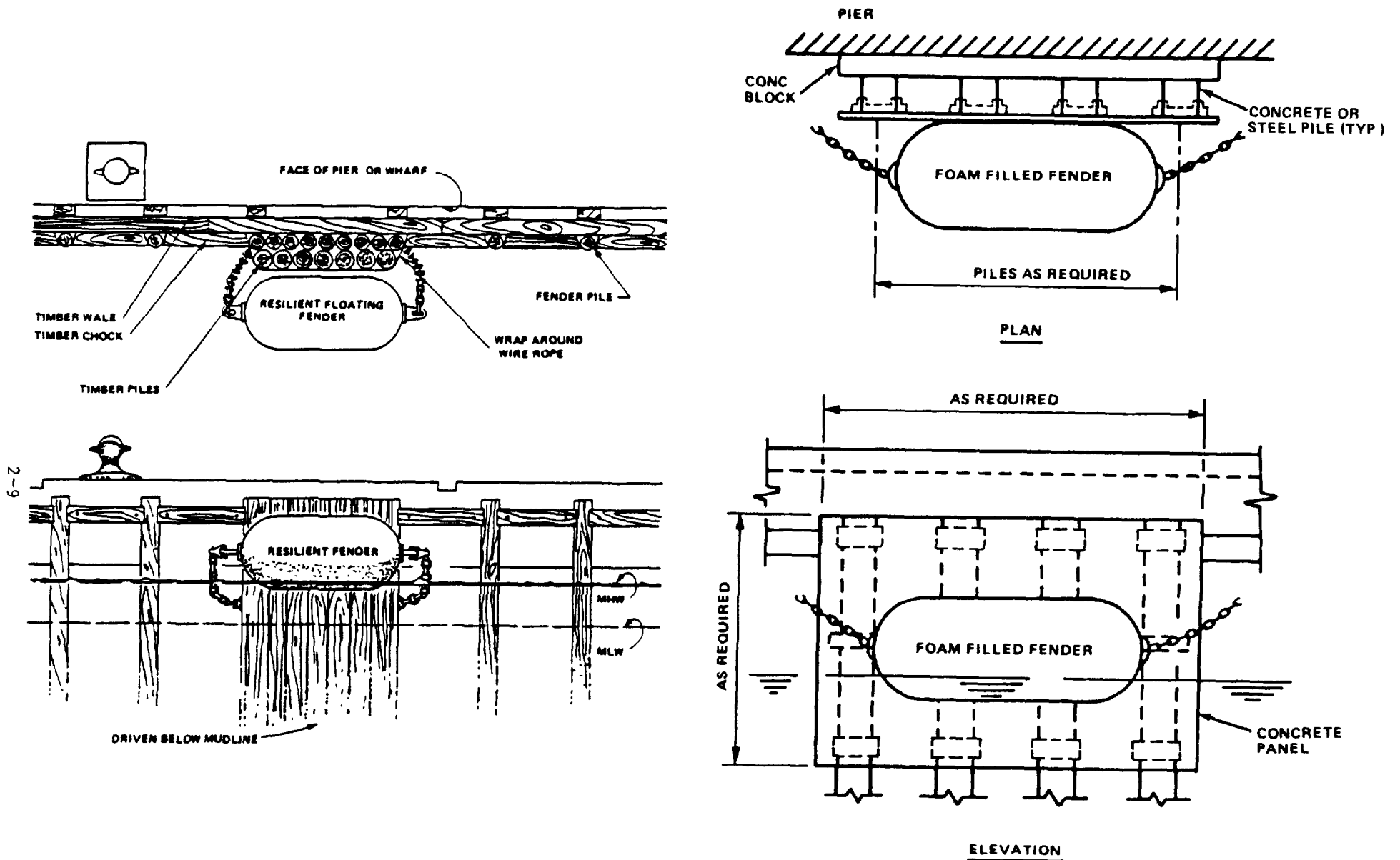


Figure 2-7. Timber Pile Cluster and Concrete Bearing Panel for Foam-Filled Fenders.

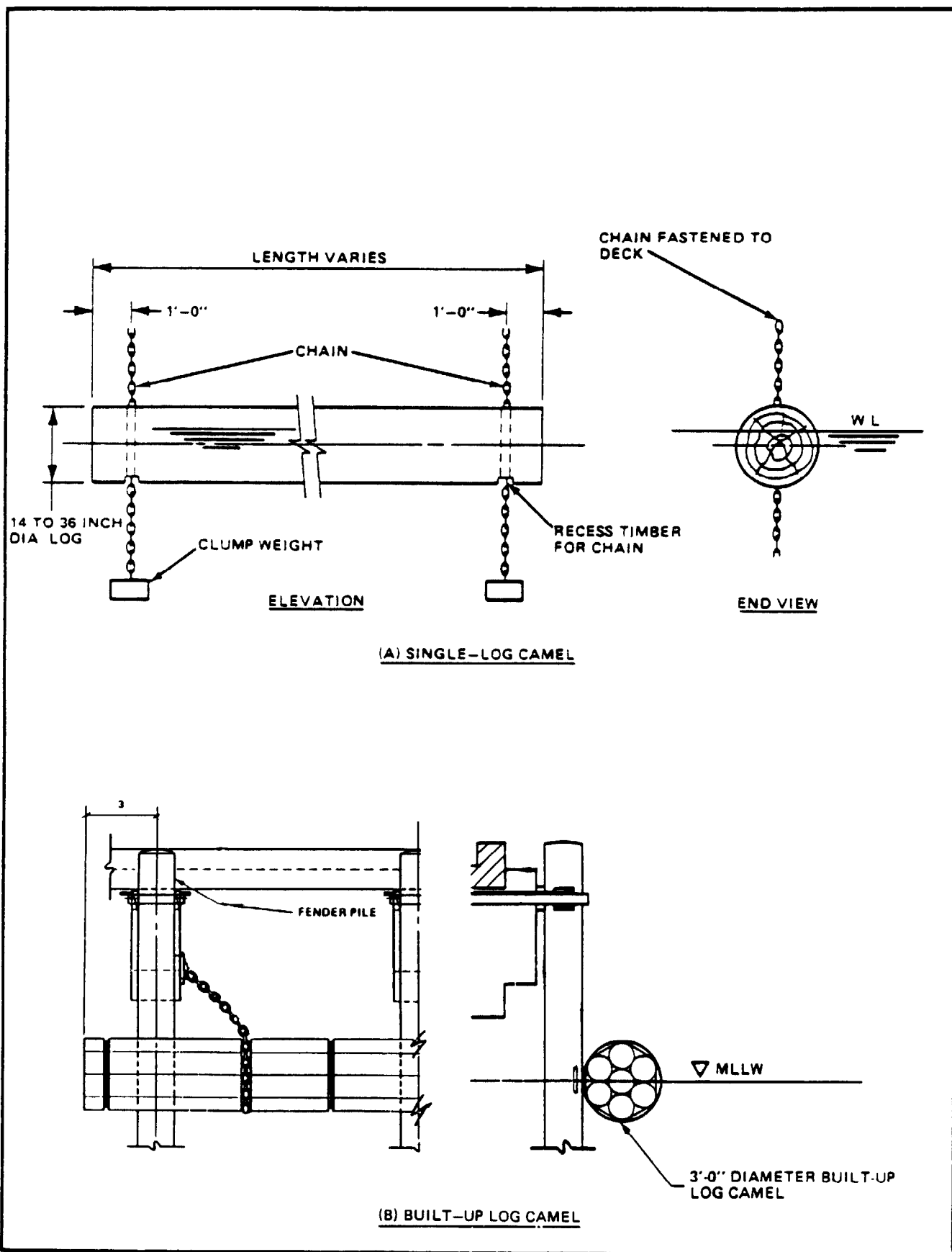


Figure 2-8. Log Camels.

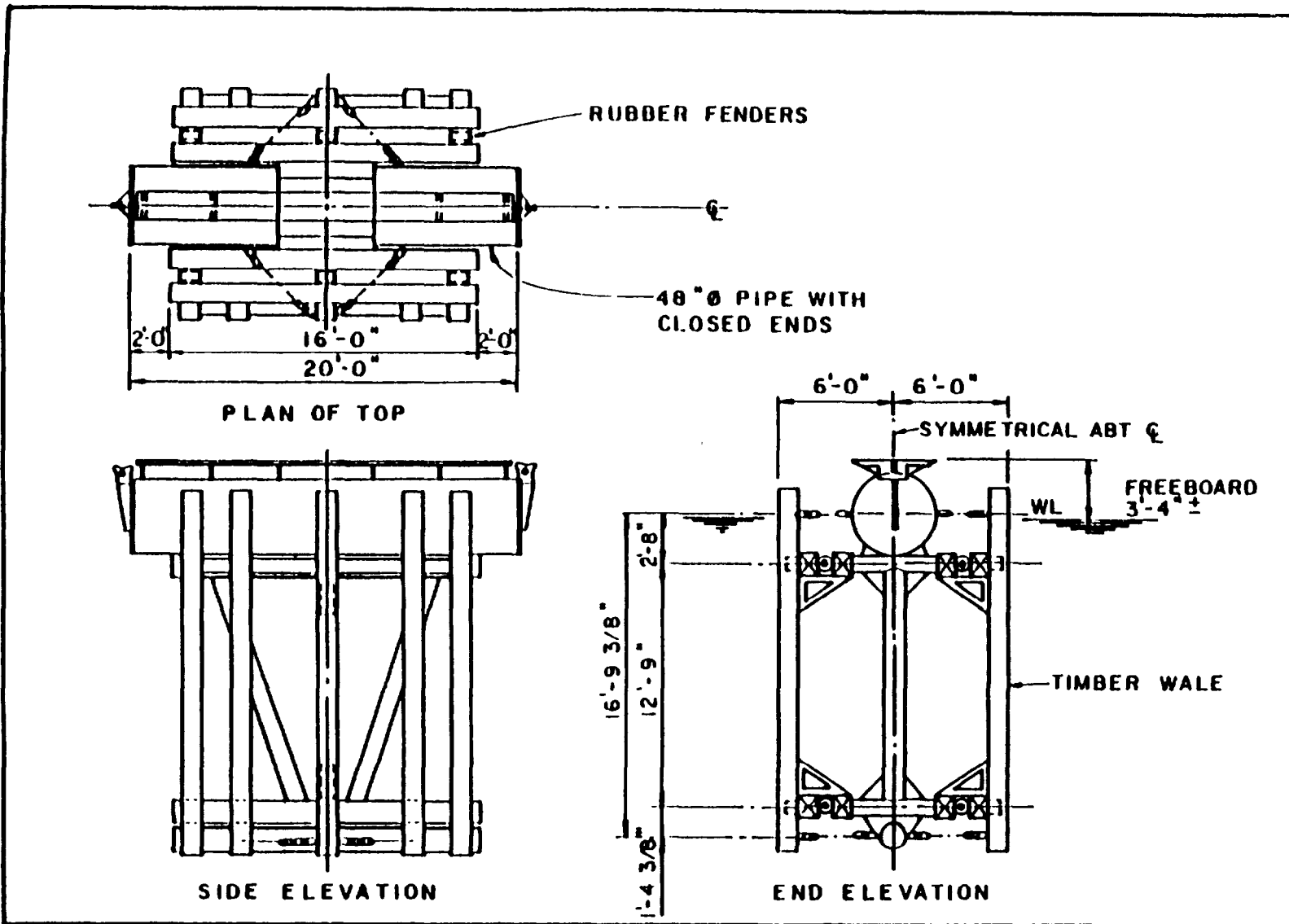


Figure 2-9. Deep Draft Submarine Separator.

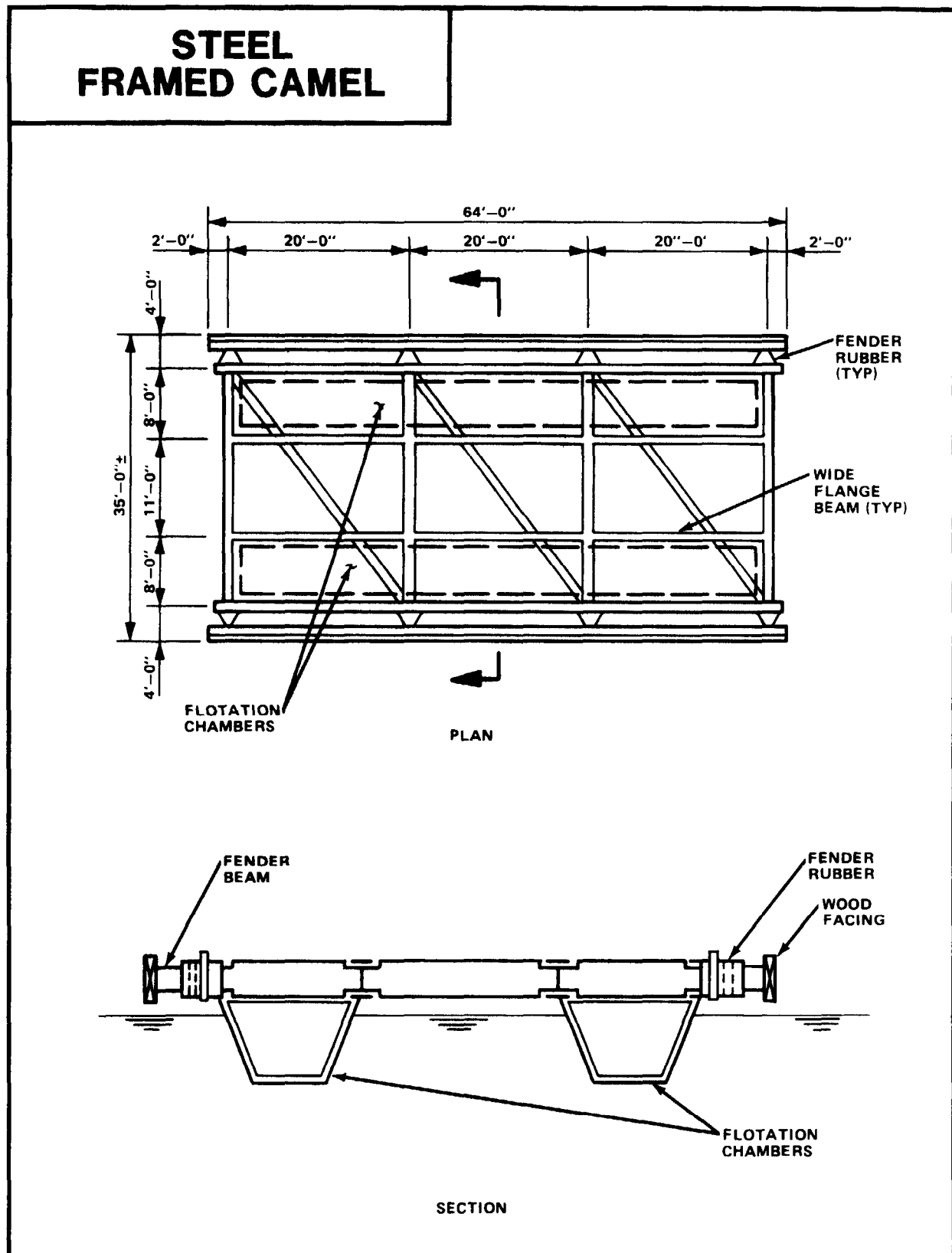


Figure 2-10. Aircraft Carrier Camel.

**2.3 SELECTING A REPLACEMENT SYSTEM.** The goals in replacing a fendering system are to:

- Provide improved protection to berthed ships and the pier.
- Decrease maintenance and repair costs.
- Decrease berth downtime due to damaged fenders.
- Increase fender system life.

The primary goal is to provide safe, reliable support to the ships. Berth availability, including adequate capacity of the system, should be the foremost consideration. Systems that require constant replacement of fender piles and repairs to other components are not only a burden on station operation and maintenance resources, but incur Fleet operational costs in berth downtime, delays in berthing, and transfer of ships to other berths.

Second to safety and availability, life cycle cost should govern the type of fendering system used. In this regard, inspection and repair records, with associated costs, are critical. Absence of proper records may lead to repetitious repairs of systems that should be replaced. The steps involved in selecting a replacement system are as follows:

- a. Analyze possible systems for practical installation and effectiveness in meeting berthing requirements. Consider ship mix, berthing and mooring forces, ship hull pressure, soil conditions, ease of driving piles, etc.
- b. Select two or more promising alternative systems for comparison.
- c. For each alternative system:
  - estimate initial cost
  - estimate life expectancy
  - develop life cycle costs
- d. Prepare a comparative life cycle cost present value analysis of the alternatives. See NAVFAC P-442 (reference 6).
- e. Estimate berth/pier downtime required for installation.
- f. Analyze potential Fleet acceptance of each system.
- g. Assess the risk of damage to a ship or the pier in the event of accidental overloading of the fender system.

The selection, then, can be made by a comparison of the elements of cost, expected life, Fleet acceptance, interruption to pier operations, and the assessment of risk of damage. For complex comparisons of several alternatives, a weighted scoring methodology may be useful. In this case, relative percentages of importance must be assigned to each element compared, and each element for each alternative fender system is assigned a score based on the analyses performed.

## CHAPTER 3. INSPECTION

### 3.1 GENERAL.

**3.1.1 The Inspection Approach.** An aggressive inspection program of fender systems, camels, and separators is essential to minimize or eliminate damage to ships and pier structures. The inspection program should consist of both operator inspection and feedback during port services operations, and scheduled facilities inspections. Timely response to reports of fender or camel damage is essential, and the inspection should produce the following information:

#### INITIAL INSPECTION

a. Identification and description of all damage and deterioration of the facility including pier locations for fender piles, and camel or separator numbers.

b. Estimate of the extent of damage and deterioration.

c. Assessment of berthing schedule requirements, if fender systems are involved.

d. Identification of any problems associated with mobilization of equipment, personnel, and materials to accomplish repairs/maintenance.

e. Documentation of types and extent of marine growth (to help plan future inspections), as well as damage caused by its presence.

f. Information for the data base of waterfront facilities and to assist in planning future inspections.

#### INSPECTION ASSESSMENT

g. Assessment of general physical condition including projected load capacities of the in-water structures of each facility inspected.

h. Assurance that the fender system was designed to handle loads of ships to be berthed.

i. Recommendations for required maintenance and repair (M&R).

j. Budgetary estimates of costs of this M&R, including examples of the derivation of the estimates.

k. Estimate of expected life of each facility.

l. Recommendations for types and frequencies of future underwater inspections.

**3.1.2 Levels of Inspection.** Three basic levels of inspection are used for inspecting marine facilities:

**a. Level I - General Visual Inspection.** This type of inspection involves no cleaning of structural elements and is the most rapid of the three types of inspection. The purpose of the Level I inspection is to confirm as-built

structural plans, provide initial input for an inspection strategy, and detect obvious damage due to overstress, impacts, severe corrosion, or extensive exposed biological attack.

**b. Level II - Close-Up Visual Inspection.** This level is to detect and identify damaged/deteriorated areas which may be hidden by surface biofouling or deterioration and to obtain a limited amount of deterioration measurements. The data obtained should be sufficient to enable gross estimates of facility usability. Level II examinations will often require cleaning of structural elements. Since cleaning is time consuming, it is generally restricted to areas that are critical or which may be representative of the entire structure. The amount and thoroughness of cleaning performed is governed by that necessary to determine the general condition of the facility.

**c. Level III - Highly Detailed Examination.** This level will normally be confined to underwater inspections, and may require the use of non-destructive testing (NDT) techniques. It may also require the use of partially destructive techniques such as core sampling into concrete and wood structures, physical material sampling, or surface hardness testing. This type of evaluation detects hidden or interior damage, loss in cross-sectional area, and material homo-geneity. A Level III examination will usually require prior cleaning. The use of NDT techniques are limited to key structural areas, areas that may be suspect, or to structural members which are representative of the underwater structure. Level III inspections will require more experience and training than Level I or Level II inspections, and should be accomplished by qualified engineering or nondestructive testing personnel.

The Level III inspection is generally reserved for structural piling and may seldom be applicable to fender piling or camels. See reference 1 for further information on Level III inspections.

**3.1.3 Planning for Inspection.** Table 3-1 lists the types of damage that are detectable with the Level I and Level II inspections. Table 3-2 provides a guide for estimating the time to perform these inspections. The inspection times were taken from references 1 and 7.

**3.1.3.1 Level I Inspections.** Level I inspections should normally be performed every 12 months by walking on the pier, camel or separator, and by using a small boat to inspect at the waterline. Recommended frequencies for inspecting camels used with submarines having Special Hull Treatment (SHT) are given in paragraph 3.9. A Level I inspection should also be scheduled upon notification of damage to a fender system or camel. Underwater inspections of prestressed concrete or steel fender piles, or major timber pile clusters, may be scheduled concurrently with the underwater inspection of the pier structural support piling. The decision to perform an underwater inspection will depend upon the life expectancy of the fender or camel system. See reference 1 for inspection planning requirements.

**Table 3-1. Capability of Each Level of Inspection  
for Detecting Damage to Fendering Systems.**

Detectable Defects				
Level	Steel	Concrete	Wood	Synthetics
I	Extensive corrosion	Major spalling and cracking	Major losses of wood due to marine borers, rot or fungus.	Chemical attack  Cracks or tears in rubber fenders or elastomer shells
	Severe mechanical damage		Broken piles, fenders, wales or chocks  Severe abrasion	Permanent set in foam-filled fenders  Damaged connectors and hardware
II	Moderate mechanical damage	Surface cracking and crumbling	External pile diameter reduction due to marine borers	Stress cracking  Punctures in rubber fenders, elastomer shells and fiberglass flotation chambers
	Major pitting	Rust staining	Splintered piling, fenders, wales or chocks	Worn areas
	Damaged welds		Early borer and insect infestation	

**Table 3-2. Production Rate for Surface and Underwater Inspection of Fixed Fender Piles.**

Structural Element	Inspection Time Per Structural Element (minutes)			
	Level I		Level II	
	Surface	U/W	Surface	U/W
12-in steel H-pile	2	5	15	30
12-in square concrete pile	2	4	12	25
12-in diameter timber pile	2	4	10	20

**3.1.3.2 Level II Inspections.** Level II inspections should be planned as follows:

**a. Fixed Steel, Concrete or Timber**

**Fender Piles.** Based upon data received from the Level I inspection, a Level II inspection may be scheduled taking into account the life expectancy of the fender pile system and the operational requirements of the pier berth. Most Level II inspections will be made from a boat at mean low water (MLW) inspecting above the waterline, including the splash and tidal zones (figure 3-1). If underwater Level II inspections are required, they should be scheduled concurrently with the inspection of pier support piling. See reference 1.

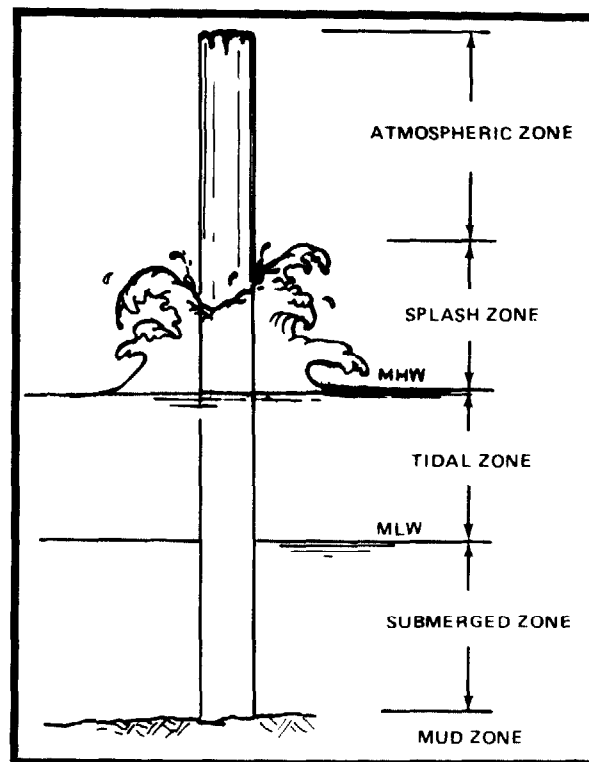
**b. Foam-Filled Fenders.** A Level II inspection will only be performed when a Level I inspection indicates a problem with the fender necessitating its removal from the water for repair. Recordkeeping for foam-filled fenders is very important. In this regard, the fenders should be treated as an item of high-cost equipment rather than an appurtenance to a fixed facility. Each fender should have a unique identification number with a history record that includes date of procurement, manufacturer, date of installation or when fender was put into service, and berth location if permanently installed.

**c. Camels and Separators.** A Level II inspection will be performed with the camel or separator out of the water. The inspection shall be scheduled, at a minimum, every three years. More frequent inspections will be required if advanced deterioration is noted during Level I inspections or if partial sinking occurs. See 3.9 concerning camels/separators used to fender submarines with SHT.

Prior to starting the Level II inspection, all available information about the facility should be collected, including prior maintenance and inspection records, facility drawings, general background information about the existing conditions of the facility and usage. A suitable scheme should also be devised for designating individual piles or pile clusters, camels and separators. Because camels and separators are relocated, identification numbers should be made a permanent part of the structures.

### 3.1.4 Equipment and Tools

**3.1.4.1 Surface Cleaning.** To perform a thorough inspection, the marine growth on the structure must be removed. For small sample areas, wire brushes, probes, and scrapers may be adequate. For larger areas or more detailed inspections



**Figure 3-1. Exposure Zones  
On Piling.**

underwater, a hydraulic grinder with barnacle buster attachment, or high-pressure water jet gun may be used, exercising care to prevent damage to the preservative-treated layers of timber or deteriorating surfaces of concrete.

#### **3.1.4.2 Inspection.** Inspection tools and equipment include:

a. **Hand-held tools** such as flashlight, ruler, and tape measure for documenting areas; hammers or pick-axes for performing soundings of the structural member; calipers and scales for determining thicknesses of steel flanges, webs, and plates; increment borer and T-handles for extracting core samples from timbers; and chipping tools for prodding the surface of the concrete to determine the depth of deterioration.

b. **Mechanical devices** including a Schmidt test hammer for measuring concrete surface hardness and rotary coring equipment for taking core samples from concrete structures.

**3.1.4.3 Recording.** Recording tools and equipment are required to provide a complete documentation of the condition of the structure. Simple tools such as clipboard, forms, and cassette recorder provide the basic documentation tools. More in depth documentation can be obtained using color still-frame cameras or color video, closed-circuit television. For special underwater inspection requirements, see reference 1.

**3.1.5 Documentation of Inspection.** For the information to be useful, documentation must be clear and concise and in accordance with generally understood terminology. Inspection forms should be filled out as the inspection progresses, and reports completed soon after the inspection. Standard forms and report formats facilitate documentation and are essential for comparing the results of the present inspection with past and future inspections. Figure 3-2 is an example of an inspection form for fender piling. Similar inspection forms should be developed and used for camels and foam-filled fenders, ensuring that each camel and fender is numbered for identification purposes.

When appropriate, visual inspection should be documented with still photography and closed-circuit television. Still photography provides the necessary high definition required for detailed analysis, while video, although having a less sharp image, provides a continuous view of the inspection. All photographs should be numbered and labeled with a brief description of the subject. A slate or other designation identifying the subject should appear in the photograph. Video tapes should be provided with a title and lead-in describing what is on the tape. The description should include the method of inspection used, the nature and size of the structure being inspected, and any other pertinent information.

**3.1.6 References.** References used to develop inspection procedures and planning factors outlined in this chapter are as follows:

- NAVFAC MO-104, Maintenance of Waterfront Facilities, Naval Facilities Engineering Command, Alexandria, VA (reference 1).
- NAVFAC MO-322, Inspection of Shore Facilities, Naval Facilities Engineering Command, Alexandria, VA, July 1977 (reference 3).

- NCEL TM-43-85-01 O&M, UCT Conventional Inspection and Repair Techniques Manual, Naval Civil Engineering Laboratory, October 1984 (reference 7).

**3.2 PERFORMING THE INSPECTION.** The procedures that follow cover Level I and Level II inspection requirements for:

- Timber fender pile systems.
- Concrete fender pile systems.
- Steel fender pile systems.
- Foam-filled fenders.
- Timber camels and separators.
- Steel framed camels and separators.

The basic approach taken in the inspection procedures is to identify potential problem areas and recommend maintenance practices to detect problem areas at an early stage.

Inspection procedures for buckling fenders and fixed and floating pneumatic fenders are not presented in this manual. General inspection of these type systems is similar to the fixed rubber fender systems and foam-filled fenders. It is recommended that the manufacturer be contacted for more detailed inspection procedures if these systems are employed.

[illegible]

**Figure 3-2. Typical Fender Piling Inspection Report Form.**

### 3.3 INSPECTION OF TIMBER FENDER PILING

#### LEVEL I INSPECTION

1. Check horizontal and vertical alignment of piles, pile clusters, wales and chocks.
2. Check piling, wales, and chocks for missing or broken members, or abrasion (figure 3-3).
3. Check pile clusters (or dolphins) for broken, worn or corroded cables and cable connectors.
4. Check for corroded, loose, broken, or missing rubbing strips, connectors, and hardware, including bolts and chains.
5. Visually examine piling, wales, and chocks for rot, fungi, and/or marine borer damage (figure 3-3).

#### LEVEL II INSPECTION

Note: A Level I inspection should have been conducted to identify areas of mechanical damage or rot, fungus, or marine borer infestation requiring a Level II inspection.

1. Start at the splash/tidal zone.
2. Clear a section of the structure of all marine growth and visually inspect it for surface deterioration. This is usually done at spot locations rather than cleaning the entire structure.
3. Sound the cleaned area with a hammer and carefully probe with a thin-pointed tool such as an icepick.
4. If an area is in question, take a small boring for laboratory analysis using an increment borer. Place a creosote treated plug in the hole to prevent easy access for marine borer entry.
5. Sound other areas of the structure with a hammer wherever there is minimal marine growth, as well as probing carefully with an icepick.
6. Record visual observations such as presence of marine borers, losses of cross-sectional area, organism-caused deterioration, location and extent of damage, alignment problems, and condition of fastenings. Use calipers and scales as required.

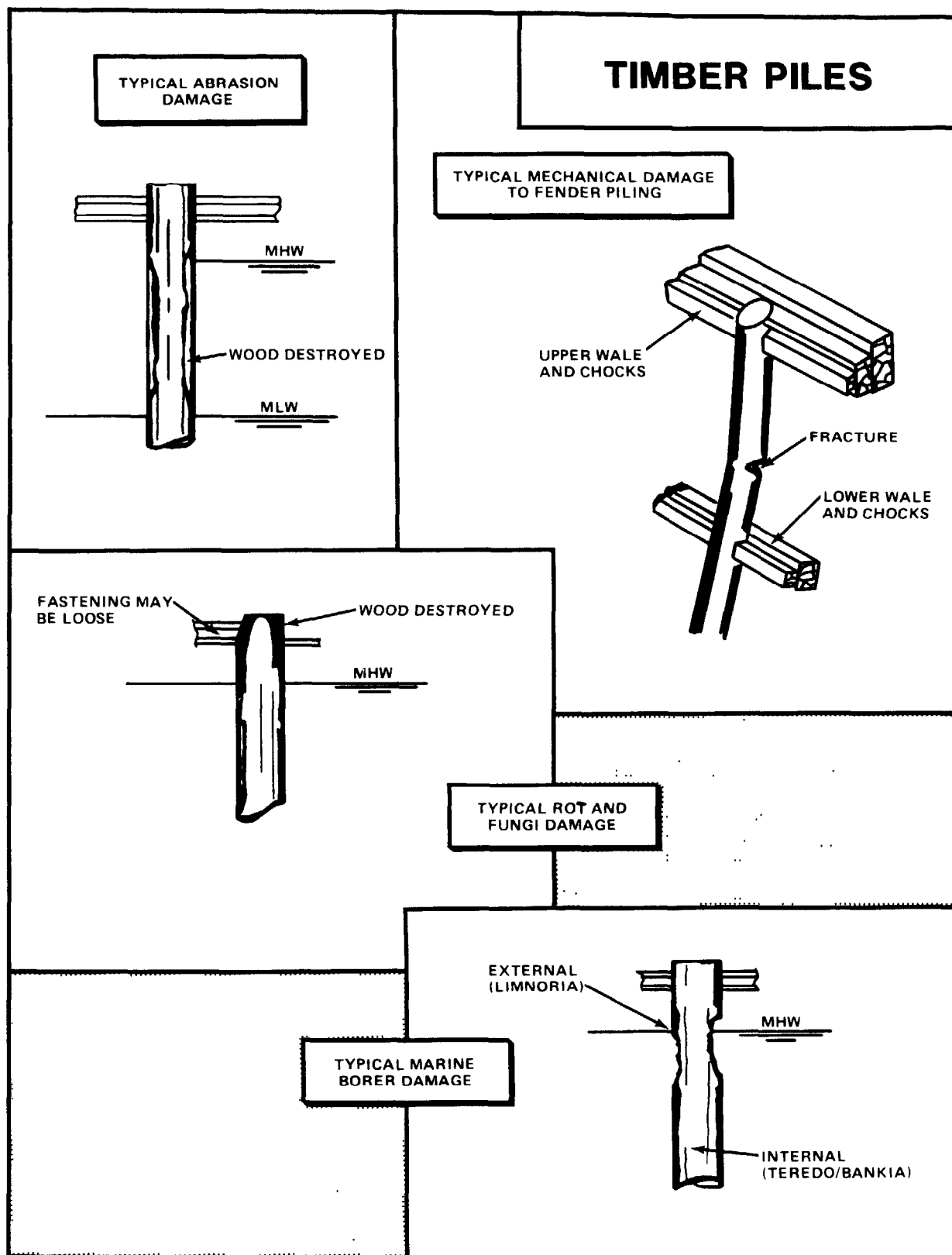


Figure 3-3. Typical Damage to Timber Fender Pile Systems.

### 3.4 INSPECTION OF CONCRETE FENDER PILING

#### LEVEL I INSPECTION

1. Check horizontal and vertical alignment of piles, wales and panels.
2. Check piling, wales, and panels for damaged or broken members, cracks and spalling of concrete, rust stains, and exposed reinforcing steel (figure 3-4).
3. Visually inspect connecting hardware (steel angles, bolts, and chains) for looseness or damage.
4. Check rubber fenders (if used) for signs of permanent set, cracking, punctures or tears.
5. Visually inspect for worn, loose, broken or missing rubbing strips (if used).

#### LEVEL II INSPECTION

Note: A Level I inspection should have been conducted to identify areas of mechanical damage or deterioration requiring a Level II inspection.

1. Inspect the structure beginning in the splash/tidal zone.
2. Clear a section about 18 to 24 inches in length of all marine growth.
3. Visually inspect this area for cracks with rust stain, broken pieces caused by spalling or mechanical damage, and exposed reinforcing steel.
4. Sound the cleaned area with a hammer to detect any loose layers of concrete or hollow spots in the pile or structure. A sharp ringing noise indicates sound concrete. A soft surface will be detected, not only by a sound change, but also by a change in the rebound, or feel, of the hammer. A thud or hollow sound indicates a delaminated layer of concrete, most likely from corrosion of steel reinforcement.
5. Dependent upon the life expectancy of the fendering systems, more sophisticated mechanical methods are available to test for quality and soundness of the concrete members. They include the Schmidt test hammers and core sampling. See reference 1 for more details.

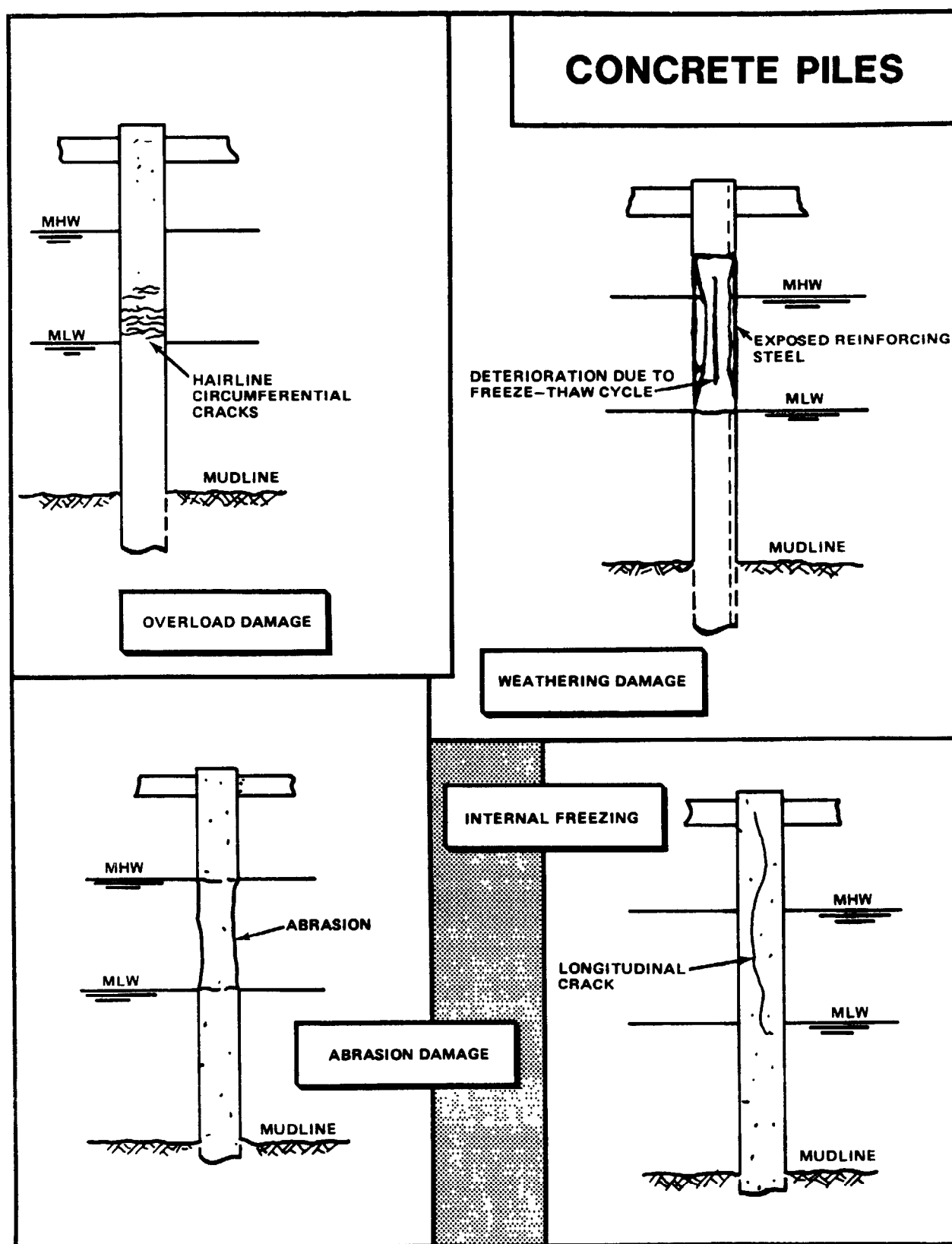


Figure 3-4. Typical Damage to Concrete Fender Pile Systems.

### 3.5 INSPECTION OF STEEL FENDER PILING

#### LEVEL I INSPECTION

1. Check horizontal and vertical alignment of piles, wales and chocks.
2. Inspect for loss of protective coating (peeling, blistering and erosion) and cathodic protection anodes, if used.
3. Check for structural damage, rust, scale and holes (figure 3-5).
4. Sound the surface with a hammer to detect any scaled steel or hollow areas.
5. Visually inspect connecting hardware (bolts and chains) for signs of looseness or damage.
6. Check rubber fenders (if used) for signs of permanent set, cracking, punctures or tears.

#### LEVEL II INSPECTION

Note: A Level I inspection should have been conducted to identify areas of mechanical damage or corrosion requiring a Level II inspection.

1. Start the inspection at the splash/tidal zone and at a depth of about 2 feet below MLW, if underwater inspection is planned.
2. Clean all marine growth from a 1-foot square section of pile and visually inspect for rust, scale, and holes.
3. If the structure has a cathodic protection system, check the cleared area with an underwater voltmeter to determine its effectiveness (underwater inspection only). Acceptable levels of cathodic protection are between -0.80 to -0.90 volt when compared to a silver/silver chloride reference cell.
4. Sound the surface with a hammer to detect any scaled steel or hollow areas.
5. Record other visual observations, such as coating condition (peeling, blistering, erosion).
6. Record the condition of cathodic protection system anodes.
7. Record the extent and type of corrosion, structural damage, or any other significant observations, using calipers and scales to determine thickness of steel flanges, webs and plates.
8. Check thoroughly all connecting hardware and welds.

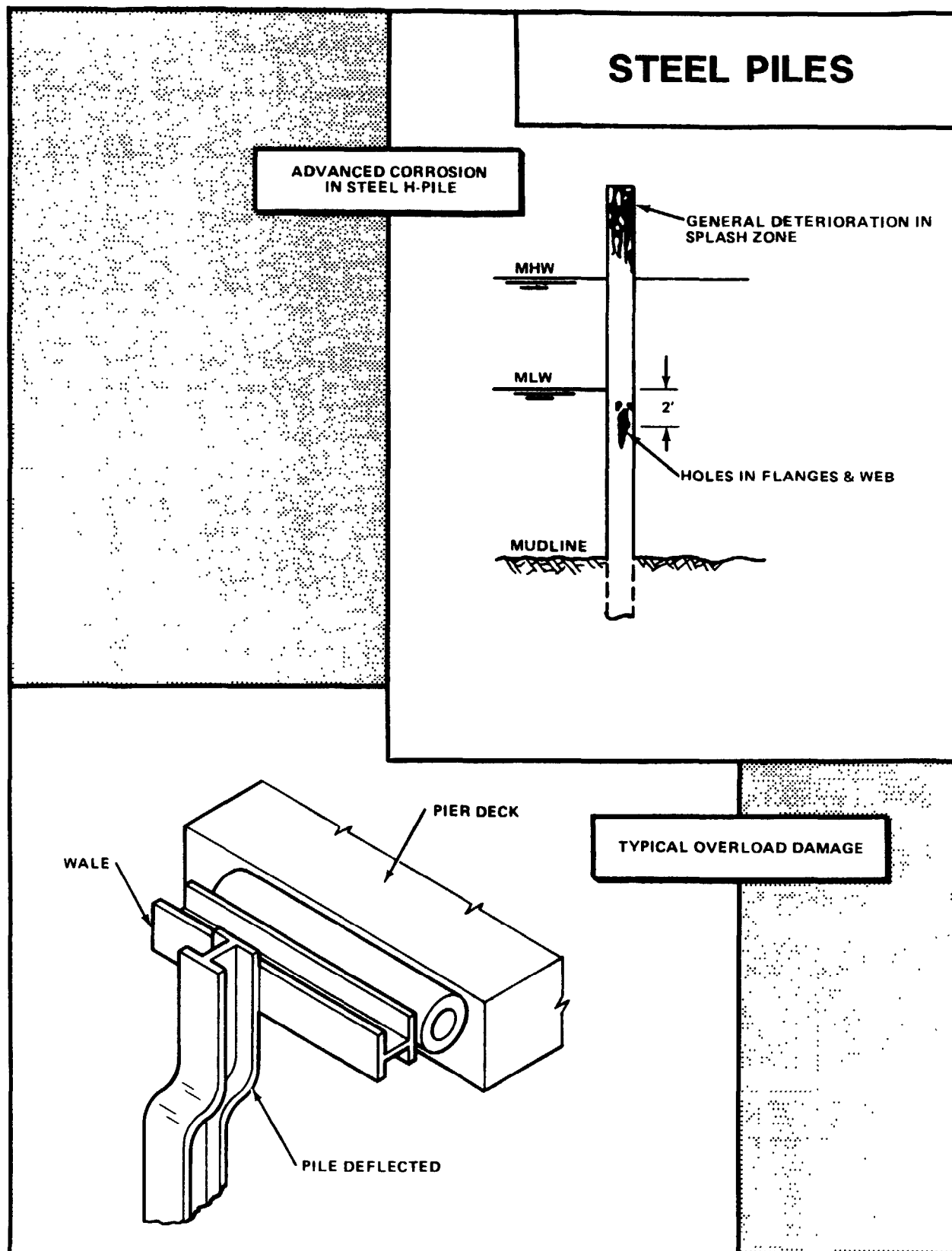


Figure 3-5. Typical Damage to Steel Fender Pile Systems.

### 3.6 INSPECTION OF FOAM-FILLED FENDERS

#### LEVEL I INSPECTION

1. Inspect condition of the fender-to-pier connection hardware (figure 3-6). Check for operability and signs of corrosion. Check to ensure that the fender is constrained horizontally so that it contacts the bearing surface for its full length. Ensure that the fender is free to float with the tide vertically and rotate around its long axis.
2. Visually inspect condition of the fender chain and tire net for net fenders. Check to see that the chain is symmetrical on the fender and that the end fittings are in good working order. Ensure that the chains are protected from the ship hull by the tires, and that the net is not loose.
3. Visually inspect condition of end fittings on netless fenders. Check to see that the fittings are in good working order and that corrosion is minimal. Check to see that the fender shell is not cracked or separated around end fittings (figure 3-6).
4. Inspect condition of the fender elastomer shell. Check for cuts, tears, and punctures. Record the size and location of damage on a sketch (figure 3-6).
5. Measure or estimate the diameter of the fender at its smallest point to record permanent set.

#### LEVEL II INSPECTION

Note: Level II inspections will be performed only when a Level I inspection indicates that the fender needs to be removed from service for repairs.

1. Provide detailed inspection of fender elastomer shell for cuts, tears and punctures. Record the size and location of damage.
2. Provide detailed inspection of end fittings on netless fenders.
3. Inspect chain, tires and connectors on net fenders.
4. Measure the diameter of the fender at its smallest point to record permanent set.

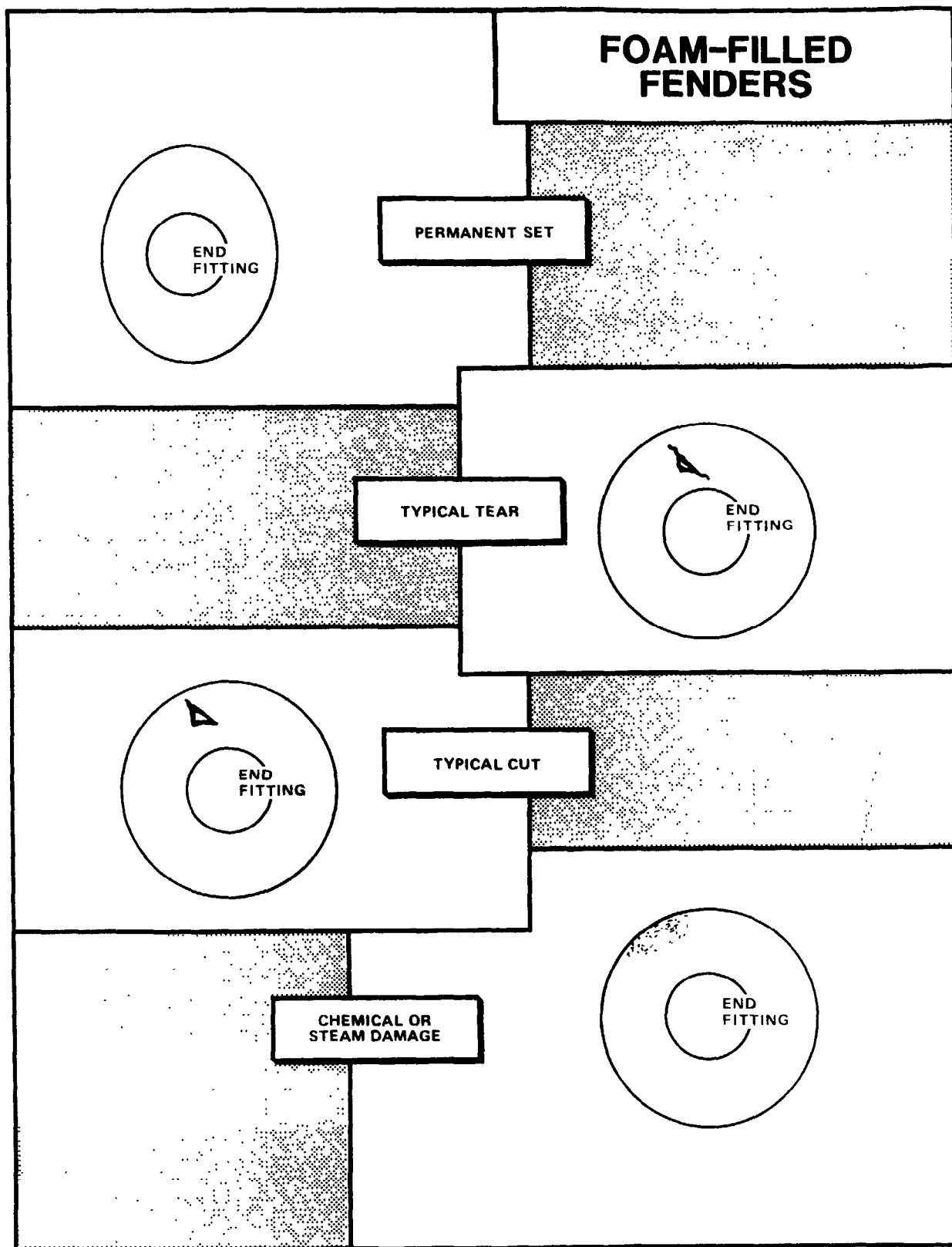


Figure 3-6. Typical Damage to Foam-Filled Fenders.

### 3.7 INSPECTION OF TIMBER CAMELS

#### LEVEL I INSPECTION

1. Check freeboard and levelness of camel.
2. Visually inspect timber members, spacers, decking, and fenders for damaged, broken or missing members (figure 3-7).
3. Visually examine decking and upper framing for signs of rot or fungus damage.
4. Inspect all visible hardware connectors (bolts, angles, chains, etc.) for signs of looseness, damage or corrosion (figure 3-7).

#### LEVEL II INSPECTION

Note: The Level II inspection will be accomplished out of water every three years or when a Level I inspection indicates that the camel needs to be removed from service for maintenance and repair.

1. Clean the camel of all marine growth and visually inspect it for surface deterioration. Spot check by sounding the structure with a hammer and carefully probe with a thin-pointed tool such as an icepick.
2. If similar areas are in question, take a representative small boring from one of the members for laboratory analysis using an increment borer. Place a creosote treated plug in the hole to prevent easy access for marine borer entry.
3. Inspect foam, if used for buoyancy, to look for signs of deterioration or decomposition from oil or other substances in the water.
4. Provide detailed inspection of all hardware fasteners.
5. Record visual observations such as presence of marine borers, losses of cross-section areas of members, organism-caused deterioration, location and extent of structural damage, alignment problems, and condition of fasteners.

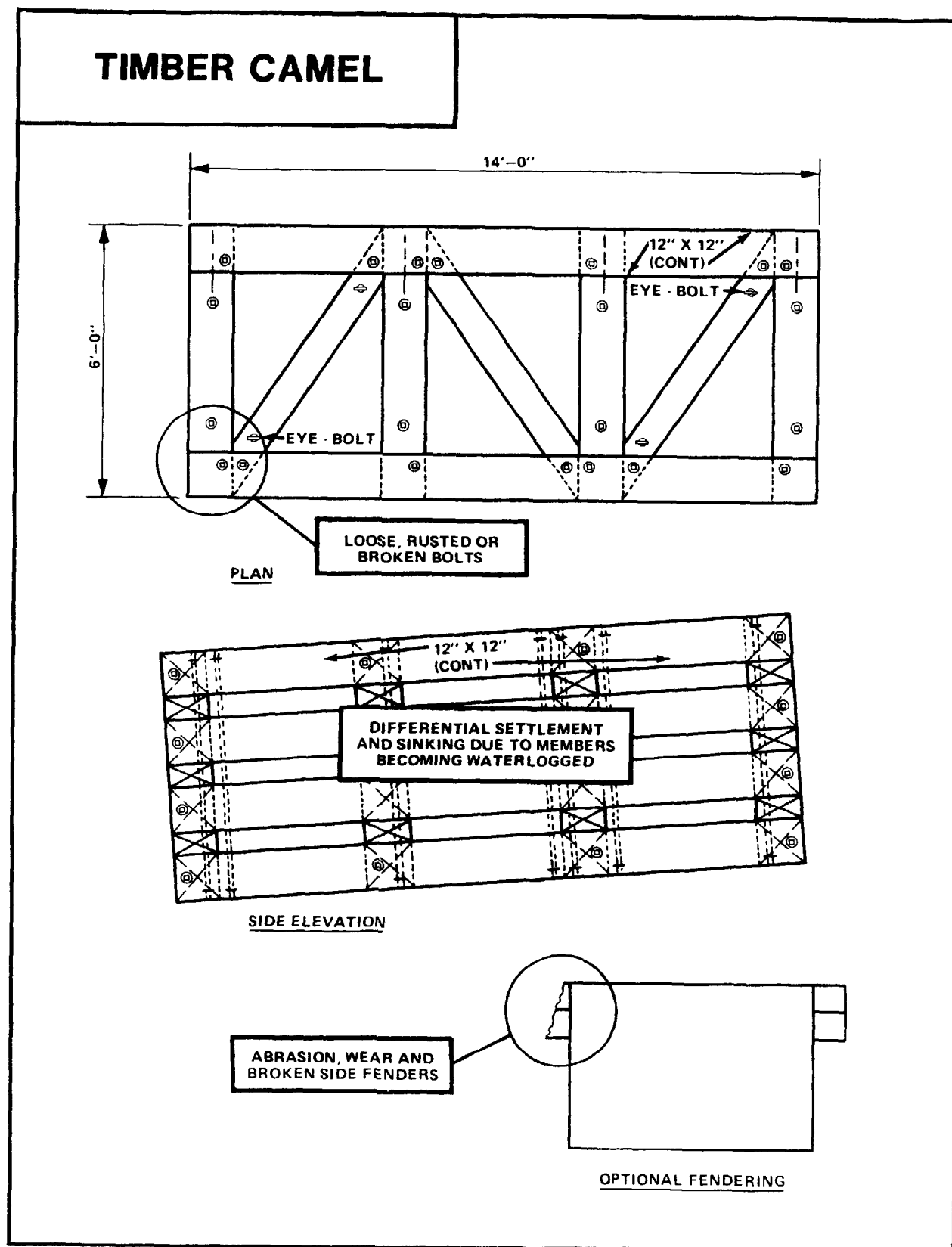


Figure 3-7. Typical Damage to Timber Camels.

### 3.8 INSPECTION OF STEEL FRAMED CAMELS

#### LEVEL I INSPECTION

1. Check freeboard and levelness of camel.
2. Inspect for loss of protective coating (peeling, blistering and erosion) on the steel and cathodic protection system anodes, if used (figure 3-8).
3. Check for structural damage, rust, scale and holes (figure 3-8).
4. Check for damaged, rusted or broken welds (figure 3-8).
5. Visually inspect wood decking, stringers, and fender strips for rot, fungus, or mechanical damage (figure 3-8).
6. Check rubber fendering for signs of permanent set, cracking, punctures or tears (figure 3-8).
7. Check for loose, damaged or missing hardware fasteners (bolts, chains, shackles, etc.).

#### LEVEL II INSPECTION

Note: A Level II inspection will be accomplished out of water every 3 years or when a Level I inspection indicates that the camel needs to be removed from service for maintenance and repair.

1. Clean all marine growth, loose paint, scale and rust from the camel and visually inspect for surface deterioration.
2. Sound the surface of the structural members, steel flotation tanks, angles, channels and welds with a hammer to detect scaled steel or hollow areas.
3. Inspect fiberglass flotation tanks (if used) for abrasions, exposed fiberglass, and punctures.
4. Record all visual observations including coating condition (peeling, blistering, erosion) and condition of cathodic protection system anodes.
5. Record the extent and type of corrosion, structural damage, or other significant observations, using calipers and scales to determine thickness of steel flanges, webs, angles and plates.
6. Inspect and record condition of all fasteners including bolts, chains, and turnbuckles.
7. Inspect and record condition of all rubber fendering for permanent set, punctures and tears.

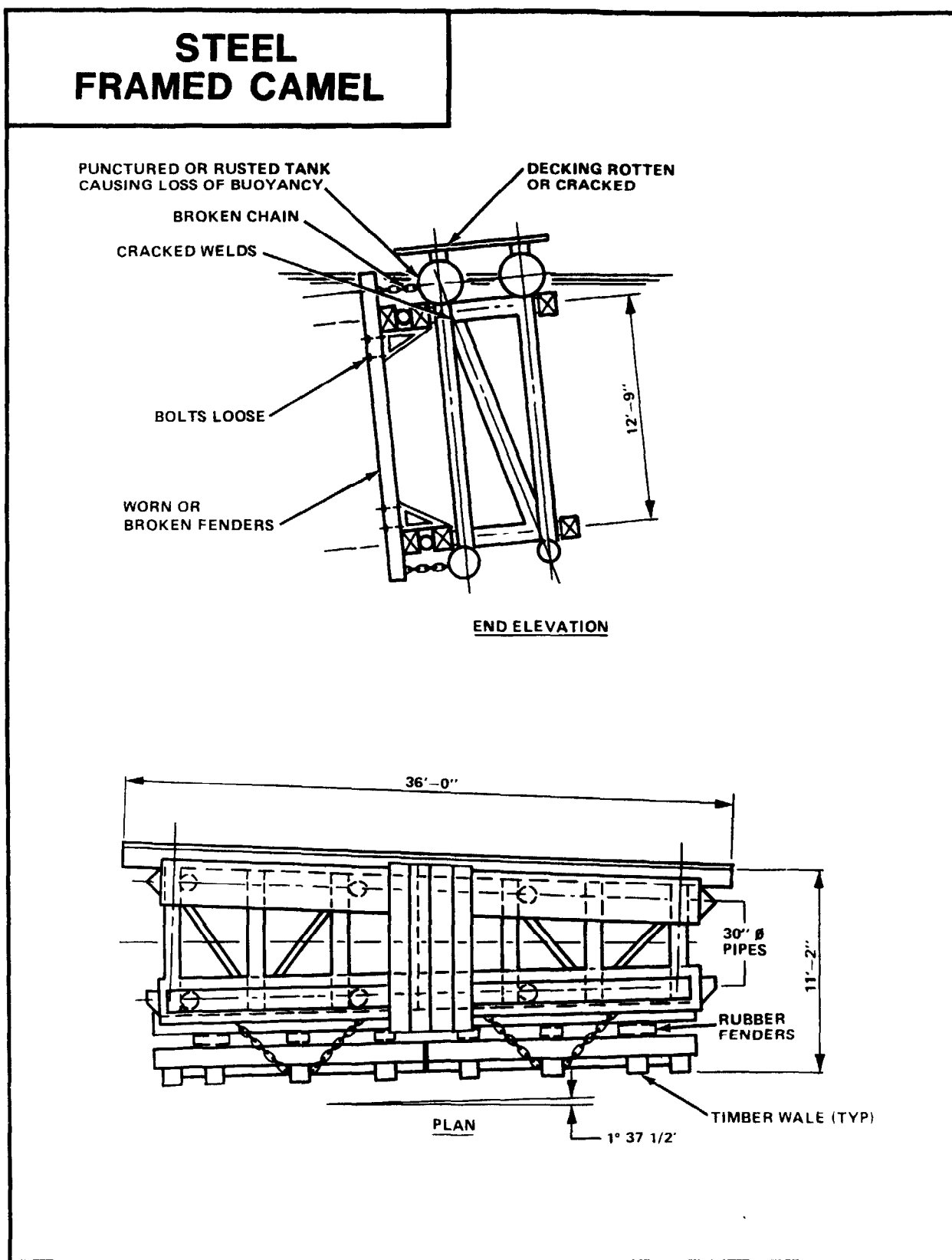


Figure 3-8. Typical Damage to Steel Framed Submarine Camels.

### 3.9 INSPECTION OF CAMELS USED TO FENDER SUBMARINES WITH SPECIAL HULL

**TREATMENT.** Special Hull Treatment (SHT) installed on certain submarines requires careful protection to prevent damage. Accordingly, the camels/separators used to fender submarines with SHT should be inspected more frequently and maintained in a condition that will ensure no damage is done to the SHT. The following are recommended inspection frequencies and special attention items.

INSPECTION LEVEL	FREQUENCY
OPERATOR INSPECTION - In water	<ul style="list-style-type: none"> <li>• Prior to berthing</li> <li>• Quarterly</li> </ul>
LEVEL I - In water	<ul style="list-style-type: none"> <li>• After submarine departure</li> <li>• After relocation of camel</li> <li>• Semi-Annually</li> </ul>
LEVEL II - Out of water or by divers	<ul style="list-style-type: none"> <li>• When camel is damaged</li> <li>• Annually</li> </ul>
TOTAL ASSESSMENT - Out of water	<ul style="list-style-type: none"> <li>• Biennially</li> </ul>

During inspections, give special attention to the following:

- Protruding bolts.
- Any item that could damage the SHT.
- Rubber fender, or other contact surface: excessive wear, damage loose or missing fasteners.
- Securing chains, lines, fittings and hardware: broken, loose, or missing parts; excessive wear, and corrosion.
- Timber: ensure that NO wood or wooden rubbing strips come in contact with the ship's hull. Check for missing or broken members, excessive wear, external decay, attack by marine borers, lack of buoyancy, excessive splitting or deflection, deterioration exceeding 40 percent of cross-sectional area.
- Steel pipes and tanks: mechanical damage, excessive wear, corrosion, lack of paint, lack of buoyancy, up to 40 percent reduction in shell thickness.
- Marine growth: barnacles and crustaceans that could damage the SHT.

## CHAPTER 4. PREVENTIVE MAINTENANCE AND REPAIR

**4.1 THE MAINTENANCE AND REPAIR APPROACH.** Proper selection of materials and component designs, taking into account operational requirements and modern technology, is absolutely essential in order to provide cost effective and reliable waterfront fendering and cameling systems to support today's ship berthing requirements. The concept of disposable timber fender piling and rigid pontoon camels may not only be expensive in the long run but may also invite extensive damage to either the ship or the pier superstructure and support systems.

The first step in any maintenance and repair decision must be to evaluate current design technologies, operational requirements, and total life cycle costs. Many integrated systems discussed in chapter 2 are now being placed into service with very cost-effective and operationally reliable results.

Once an optimum design that meets operational requirements has been identified, preventive maintenance measures including wood preservatives, coatings, special concrete mixtures, cathodic protection, and/or selection of alloys and synthetic materials need to be adopted to aid in extending the life of the materials and structures.

When the facility is placed into service, an aggressive repair program becomes essential if continued usage of the facility is planned and if escalating repair costs are to be avoided. Postponing the repairs can lead to more costly replacement or possible downgrading of the operational capabilities of the facility.

The selection of repair method to be used must consider the following elements:

- Facility mission and required life.
- Extent of damage and deterioration.
- Estimated life expectancy with and without repairs.
- Projected load capacities with or without repairs.
- Problems associated with mobilization of equipment, personnel, and materials to accomplish repairs/maintenance.
- Economic trade-offs.

**4.2 REFERENCES.** Material used to develop maintenance and repair techniques and planning factors outlined in this chapter were taken, in part, from the following documents:

- NAVFAC MO-104, Maintenance of Waterfront Facilities, Naval Facilities Engineering Command, Alexandria, VA (reference 1).

- NCEL TM-43-85-01 O&M, UCT Conventional Inspection and Repair Techniques Manual, Naval Civil Engineering Laboratory, October 1984 (reference 7).
- NCEL TM 53-89-03, Prestressed Concrete Fender Piling User Data Package, Naval Civil Engineering Laboratory, December 1988 (reference 8).
- CEL CR 81.009, Survey of Techniques for Underwater Maintenance/Repair of Waterfront Structures, Naval Civil Engineering Laboratory, Childs Engineering Inc., April 1981 (reference 9).
- Survey of Techniques for Underwater Maintenance/Repair of Waterfront Structures, Revision No. 1, Naval Civil Engineering Laboratory, Childs Engineering Corporation, December 1986 (reference 10).
- NAVDOCKS MO-306, Corrosion Prevention and Control, Naval Facilities Engineering Command, Alexandria, VA, June 1964 (reference 11).
- NAVFAC MO-110 (Tri-Service), Paints and Protective Coatings, Naval Facilities Engineering Command, Alexandria, VA, June 1981 (reference 12).
- NAVFAC MO-307, Cathodic Protection Systems - Maintenance, Naval Facilities Engineering Command, Alexandria, VA, May 1981 (reference 13).

**4.3 WOOD AND TIMBER STRUCTURES.** Wood and timber are widely used for fender systems and camels. Typical applications include:

- Timber fender systems.
- Timber wales and chocks for steel and concrete fender systems.
- Timber rubbing strips for concrete or steel fender piles.
- Timber framed camels.
- Log camels.
- Timber fendering and decking for steel framed camels.

Maintenance of wooden structures involves replacement of decayed and damaged wood and the application of a preservative or coating. If repairs are to be reduced in the future, exposed wood used in the splash zone must be treated with an effective preservative or coating system to retain its strength and longevity against severe weathering, effects of saltwater, and destructive fungi, marine organisms, insects, and bacteria attack. See references 14 and 15 for more detailed descriptions of wood deterioration by fungus, insect and marine borer attack.

The common types of lumber used in the United States are Douglas fir, southern pine, spruce, hemlock, redwood, cedar, and other pine species such as lodgepole, ponderosa, and white. Primarily, Douglas fir is used on the West Coast and southern pine is used on the East Coast due to availability. Round timber piles are made from Douglas fir or southern pine according to availability and size requirements for piling. These piles should conform to the DoD adopted specification, American Society for Testing and Materials (ASTM) D 25, and the guidelines in NAVFAC Guide Specification NFGS-02361. The various other types of lumber should conform to standards set by the American Lumber Standards Committee (ALSC) and should be properly graded and marked before acceptance.

**4.3.1 Preventive Maintenance for Wood and Timber.** The primary PM measure at the waterfront is to select the type of wood best suited for the particular use and to purchase wood products and timber piles which have been treated with quality preservatives and methods. The most important field PM are those actions to preserve wood and timber with paint and other coatings. Field techniques should be used to eliminate or minimize cuts and holes made in the members at the site, particularly those made below water. If cuts and holes are made, special field PM preservative treatment is required. In addition, there are other PM measures applicable to timber piles using encasements and retardants. Specifications and standards applicable to the preservation of wood are listed in appendix A.

**4.3.1.1 Pressure Treatment.** Pressure treatment of the outer sapwood of timbers with preservatives is the most important and effective method of protecting wood. It permits deeper and more uniform penetration of preservative, and closer control of retention levels. The preservative penetrates the wood from 0.5 inches to 4.0 inches, depending on the type of wood, and provides protec-

tion from fungi, marine borers, insects and bacteria. The American Wood Preservers Bureau (AWPB), the American Wood Preservers Association (AWPA), and Federal Specification TT-W-571 govern the treatment processes that must be performed on wood used in waterfront areas. In the field, pile cutoffs, framing cuts, and holes that expose untreated wood to the environment are treated as discussed in paragraph 4.3.1.2.

The choice of preservative treatment depends on how and where the wood is to be used. Wood preservatives are classified in three categories: creosote preservatives, oil-borne preservatives, and water-borne preservatives.

**Creosote preservative** and creosote solutions are the most commonly used preservatives for timber fender piling and camels because they are not easily leached from the wood and are not corrosive to metals. Creosote and creosote-coal tar solutions, both derived from bituminous coal, can be used for immersed wood. Creosote is commonly diluted with petroleum oil for treatment of wood not subject to immersion. An important disadvantage of creosoted piling, however, is the fact that it is readily attacked by the marine borer, *Limnoria tripunctata*. Also, creosote and creosote solutions cannot be used where it may come in contact with people.

**Oil-borne preservatives** are dissolved in a petroleum solvent and include pentachlorophenol, copper naphthenate, tributyl tin oxide, and copper-8-quinolinolate. Oil-borne preservatives are suitable for wood members out of the water for protection against insects and fungi. Treated wood can be painted, does not swell and distort, is easily handled, and will not corrode metal. Before the solvent evaporates, it is more flammable than untreated wood. Pentachlorophenol is the most effective of these preservatives but is also highly toxic.

**Water-borne preservatives** are toxic metallic salts dissolved in water for easier application. The most common water-borne preservative is chromated copper arsenate (CCA). Wood pressure treated with CCA or ammoniacal copper arsenate (ACA) can be used either above or below the waterline. Either of these salts in combination with creosote (dual treatment) is more effective in preventing marine borer damage than any single treatment. Other waterborne preservatives for use above the waterline include chromated zinc chloride, fluorochrome-arsenate-phenol, and acid copper chromate.

All preservative treatments have drawbacks that should be considered. Metallic salts, for example, can embrittle wood. More importantly, these toxic chemicals present environmental and personnel safety problems. Proper safety, installation, and disposal procedures should be carefully followed.

**4.3.1.2 Treating Exposed Areas of Wood.** Cut surfaces of wood members, pile cutoffs, bolt holes, and any other exposed surfaces of treated wood members must be treated in the field. Prior to treatment, any grease or oil must be removed by solvent cleaning as described in SSPC SP-1. Cut surfaces and pile cutoffs should be treated in accordance with AWPA Standard M4. Pile cutoffs should then be painted with coal tar pitch. Holes for bolts and plugs in piles and timbers should be treated with the same type of wood preservative used for the member. Bolt holes should be treated under pressure with a mechanical bolt hole treater, if available, or thoroughly doused to saturation.

**4.3.1.3 Added Protection for Timber Piles.** All timber piling in the marine environment, including piling properly treated, are eventually attacked by wood destroying organisms. Pilings are also commonly subject to icelift and abrasion. As a result, protection with plastic wraps and/or rubbing strips is often required, in addition to preservative treatment, in order to minimize the impact of these environmental factors.

The use of plastic wrapping to protect piling against marine borer damage at and below the waterline does offer, under certain conditions, considerable economic benefit by effectively eliminating borer damage, reducing future repair costs. The polyvinyl chloride (PVC) and polyethylene wrapping smothers borers already in the wood and prevents the entry of more borers. Care must be taken to prevent and repair breaks and tears in the wrapping to maintain its protective integrity. This protection may be particularly advantageous with pile clusters. Fender piles prewrapped with a thick, heatshrink polyethylene are provided with a slippery surface that prevents exposure of untreated wood due to wear from camels. An example of a molded polyethylene jacket used for ice protection is shown in figure 4-1.

The use of plastic or metal rubbing strips, as shown in figure 4-2, on individual piles making contact with steel or timber camels is essential to minimize wear by abrasion. Usage on pile clusters may be advantageous depending on the type cameling planned for use by the activity.

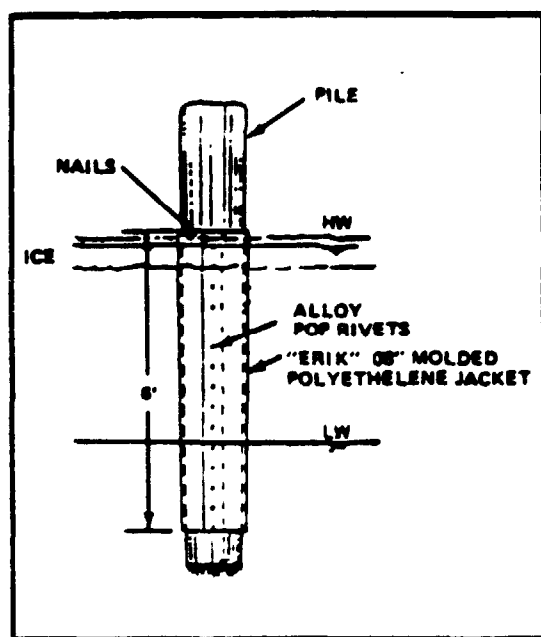


Figure 4-1. Timber Pile Jacket.

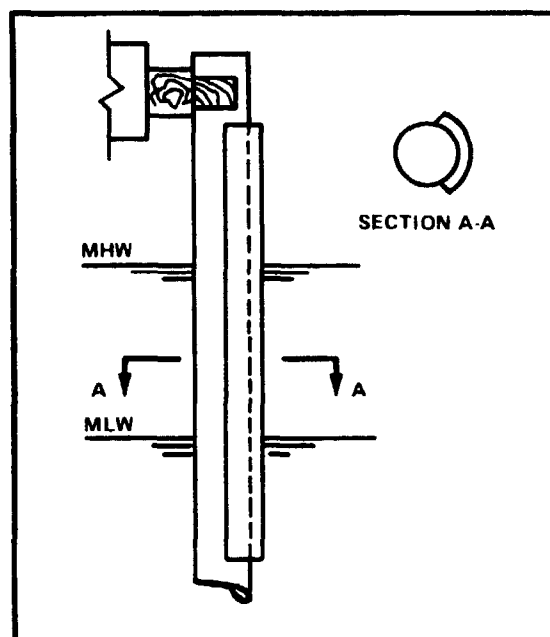


Figure 4-2. Rubbing Strip on Timber Fender Pile.

## 4.3.2 Repairs to Timber Fender Piles and Camels

**4.3.2.1 Timber Fender Piles.** Repair methods for timber fender pile systems are generally directed at correcting one or more of the following problem areas: fungi and/or insect attack, marine borer deterioration, abrasion, and mechanical damage caused by impact during ship berthing or mooring operations. Abrasion and mechanical damage generally dictate the repair actions. As a result, repairs usually consist of total replacement of piles, wales, chocks, and connecting hardware.

**4.3.2.2 Timber Camels.** Repair methods for timber camels are generally directed at replacing damaged members (mechanical wear) and broken or loose bolts. Other repair requirements include:

- Replacement of deteriorated foam, if used for flotation.
- Replacement of waterlogged members or members experiencing marine borer deterioration.

**4.3.2.3 Planning the Repair.** The initial planning step is a review of prior inspection reports to determine the scope of deterioration, the rate of deterioration, and specific operational constraints placed upon the facility because of the deterioration. Once the scope of repair requirements, including priorities, are established, the type of replacement system and method of accomplishment may be determined.

If the frequency and cost of repairs are high, an alternate fendering or camel system should be considered. Skills and equipment requirements to perform repairs are generally common to the activity's wharfbuilding trade or local commercial capabilities.

Underwater repairs require special skill levels and equipment that may not be available in-house. Skills include knowledge of removal of marine growth, jetting or air lifting procedures, underwater cutting and drilling techniques, and jacketing and wrapping materials used in underwater construction. Equipment for underwater repairs may include: high-pressure water blaster, hydraulic grinders with barnacle buster attachment, hydraulic drill with bits, hydraulic power unit, hydraulic chain saw, concrete pump with hosing, jetting pump and hose, rigging equipment, float stage and scaffolding, clamping template for cutting piles, and special clamping equipment. Reference 1 covers the underwater repairs in more detail.

### 4.3.2.4 Repair Procedures

**a. Timber Fender Piles.** Repair procedures for waterfront wood and timber fender piling include:

- Repairing timber fender pile by splicing.
- Replacing timber fender piles, wales, chocks, and hardware.

b. **Timber Camels.** Repair procedures for timber camels include replacing damaged or waterlogged members, or damaged hardware. Every effort should be made in transport and handling to prevent damage to treated piles and timbers, particularly in portions of the work exposed to marine borer attack. Care should also be taken in driving piles to prevent checking or splitting of the treated wood. Butts should be trimmed and headed so that the hammer will strike only untreated wood. Piles and timbers should be inspected before and during the time they are driven or placed. Where the protective preservative shell is broken or damaged in any way, the holes and/or crevices should be repaired by drilling, and neatly and tightly plugged in accordance with AWPA Standard M4. Where abrasions or other damages cannot be sealed against marine borers, other protection must be provided in an approved manner. All wood and timber members should be handled in accordance with AWPA Standard M4.

## REPAIRING TIMBER FENDER PILE

**Problem:** Fender pile broken between upper and lower wale. Lower portion of pile basically maintains original alignment.

**Description of Repair:** Cut off pile just below the break. Install a new section of pile and secure with epoxy cement (figure 4-3). Fit and bolt a strongback pile or timber section in place directly behind the fender pile and between the top and bottom wales. Attach a metal shoe (wearing strip) to the wearing edge of each fender pile. The level of treatment to be applied to the fender piles will be determined at the activity level based on estimated life expectancy of the pile. Larger piles (18-inch diameter) or pile clusters should be treated for preservation against marine borers, fungus and insects.

Decayed, marine borer damaged, or broken fender piles that cannot be adequately repaired should be pulled and replaced with new piles. Installation of a steel shoe on the outer surface of each fender pile is recommended.

Deteriorated chocks should be replaced with tightly fitting chocks that are bolted to one string piece or to a wale below the deck. Treatment requirements will be locally determined.

Deteriorated or damaged wales should be replaced with the same size and length as the original wales unless redesigned. Treatment requirements for the wales will be locally determined.

**Application:** The method of repair by sectional replacement is generally limited to piers berthing tugs, barges, etc. where damage is sporadic and infrequent, making mobilization of a full wharf building crew uneconomical.

**Future Inspection Requirement:** The inspection frequency should be based upon historical records of fender pile damage.

## REPAIR TIMBER FENDER PILE

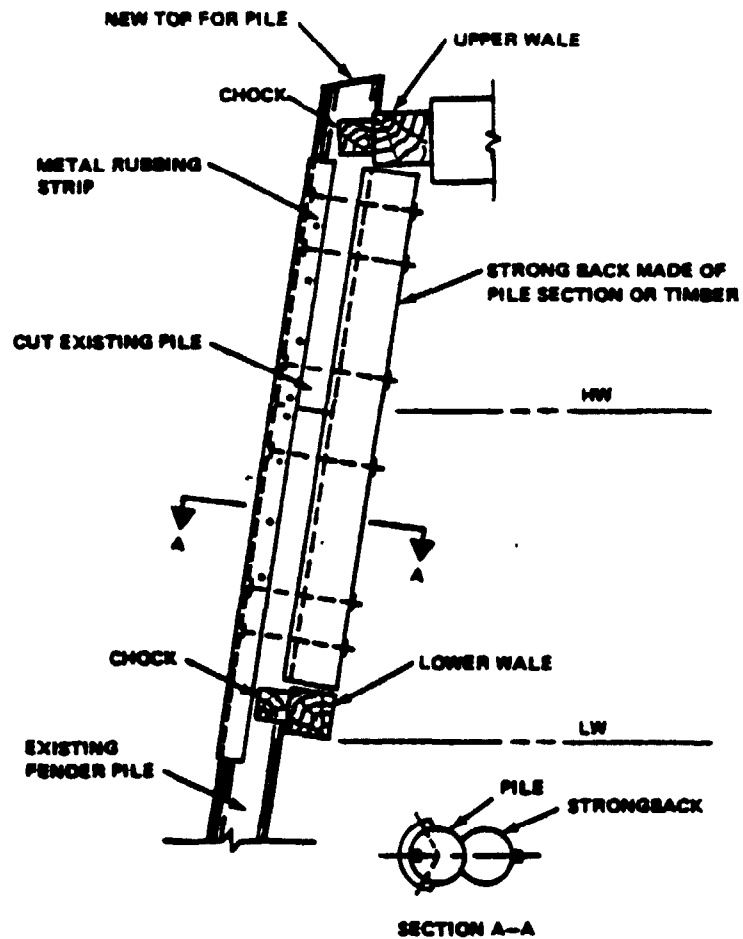


Figure 4-3. Repair by Splicing Timber Fender Pile.

## REPLACING TIMBER FENDER PILE

**Problem:** Fender pile broken or missing; wales and chocks broken, missing or misaligned; and lower portion of pile out of alignment.

**Description of Repair:** Remove damaged upper section of pile, wales, chocks and hardware. Pull pile base or cut at mudline. Drive a new pile or pile cluster cut to match the elevation of adjacent timber fender piles (figure 4-4). Install galvanized bolts and plastic or metal rubbing strips.

Deteriorated chocks should be replaced with tightly fitting chocks that are bolted to one string piece or to a wale below the deck. Treatment requirements will be locally determined.

Deteriorated or damaged wales should be replaced with the same size and length as the original wales unless redesigned. Treatment requirements for the wales will be locally determined.

Exercise care in rafting and handling to prevent damage to treated piles and timbers, particularly in portions of the work exposed to marine borer attack. Care should also be taken in driving piles to prevent checking or splitting of the treated wood. Butts should be trimmed and headed so that the hammer will strike only untreated wood. Piles and timbers should be inspected before and during the time they are driven or placed. Where the protective preservative shell is broken or damaged in any way, the holes and/or crevices should be repaired by drilling, and neatly and tightly plugged in accordance with AWPAs Standard M4. Where abrasions or other damages cannot be sealed against marine borers, other protection must be provided in an approved manner. All piles should be handled in accordance with AWPAs Standard M4.

**Application:** Replacement of individual timber fender piles, using the same pile configuration, should be accomplished only when operational or economic constraints preclude using an improved pile system. See chapter 2 for guidance.

**Future Inspection Requirement:** Close monitoring of fender performance will be required to document rate and frequency of damage. Level I inspections every 3 months may be required if accelerated wear or damage is noted. Good documentation of maintenance/repair history is essential.

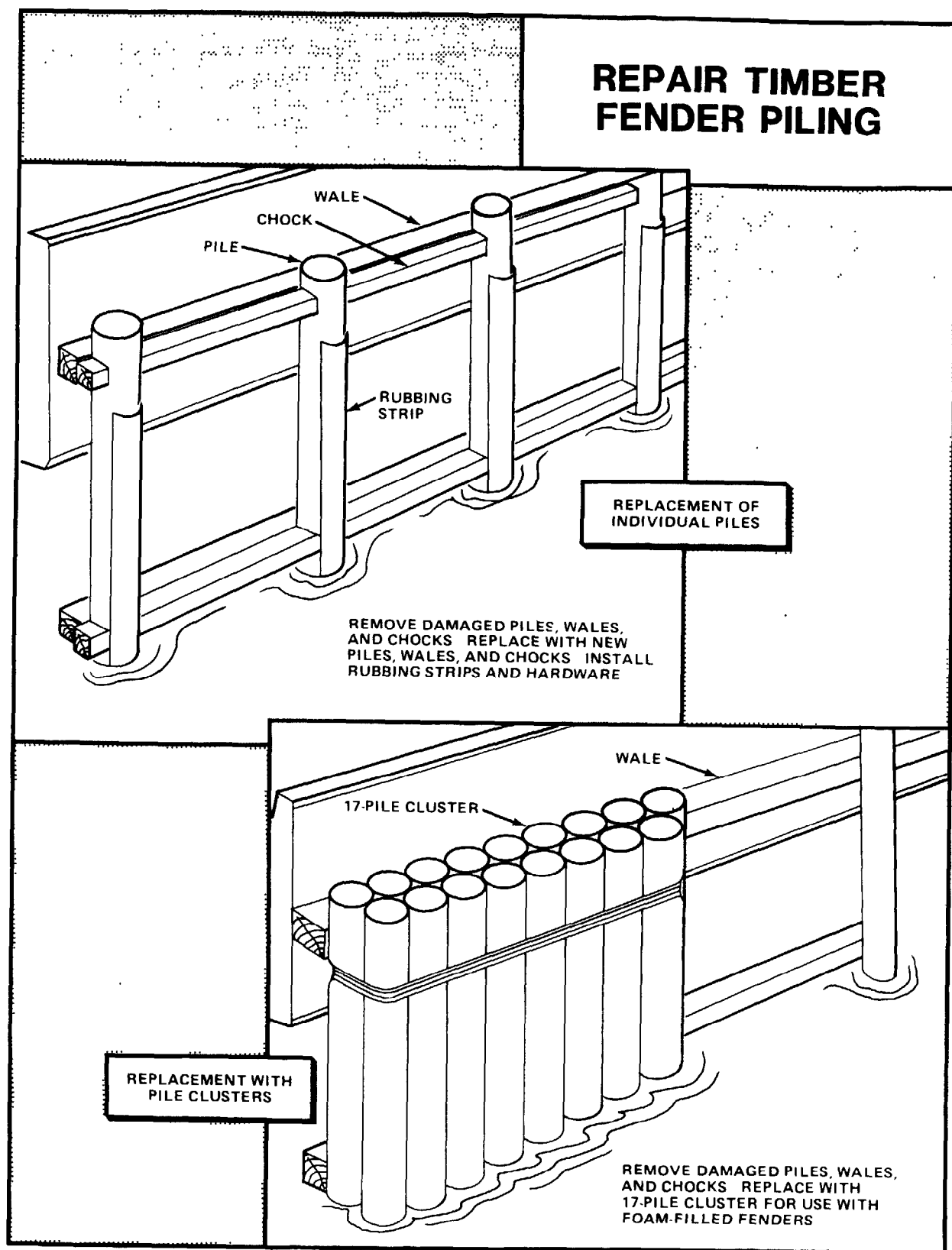


Figure 4-4. Replacing Damaged Fender Piling With New Timber Piling.

## REPAIRING TIMBER CAMEL

**Problem:** Timber camel has worn or damaged members; loose, damaged, or missing hardware; waterlogged members causing listing or loss of free-board; or marine borer deterioration.

**Description of Repair:** Remove the camel from the water, thoroughly clean the camel of all marine growth, and inspect for surface deterioration. Spot check suspected areas by sounding with a hammer and probing with a thin-pointed tool. Inspect all bolts and other hardware. Replace structural members and hardware as required. Ensure that all cut surfaces are treated in accordance with AWWA Standard M4, and that all bolt holes are treated under pressure with a mechanical bolt hole treater, if available, or thoroughly doused to saturation. Return the camel to service ensuring that all maintenance records are updated covering the specific camel.

**Application:** Frequency of repair requirements, age, and repair costs will normally govern whether the timber camel is repaired, replaced by another timber camel, or replaced by an alternative camel system.

**Future Inspection Requirements:** The inspection frequency should be based upon the age of the facility and historical records of the specific camel.

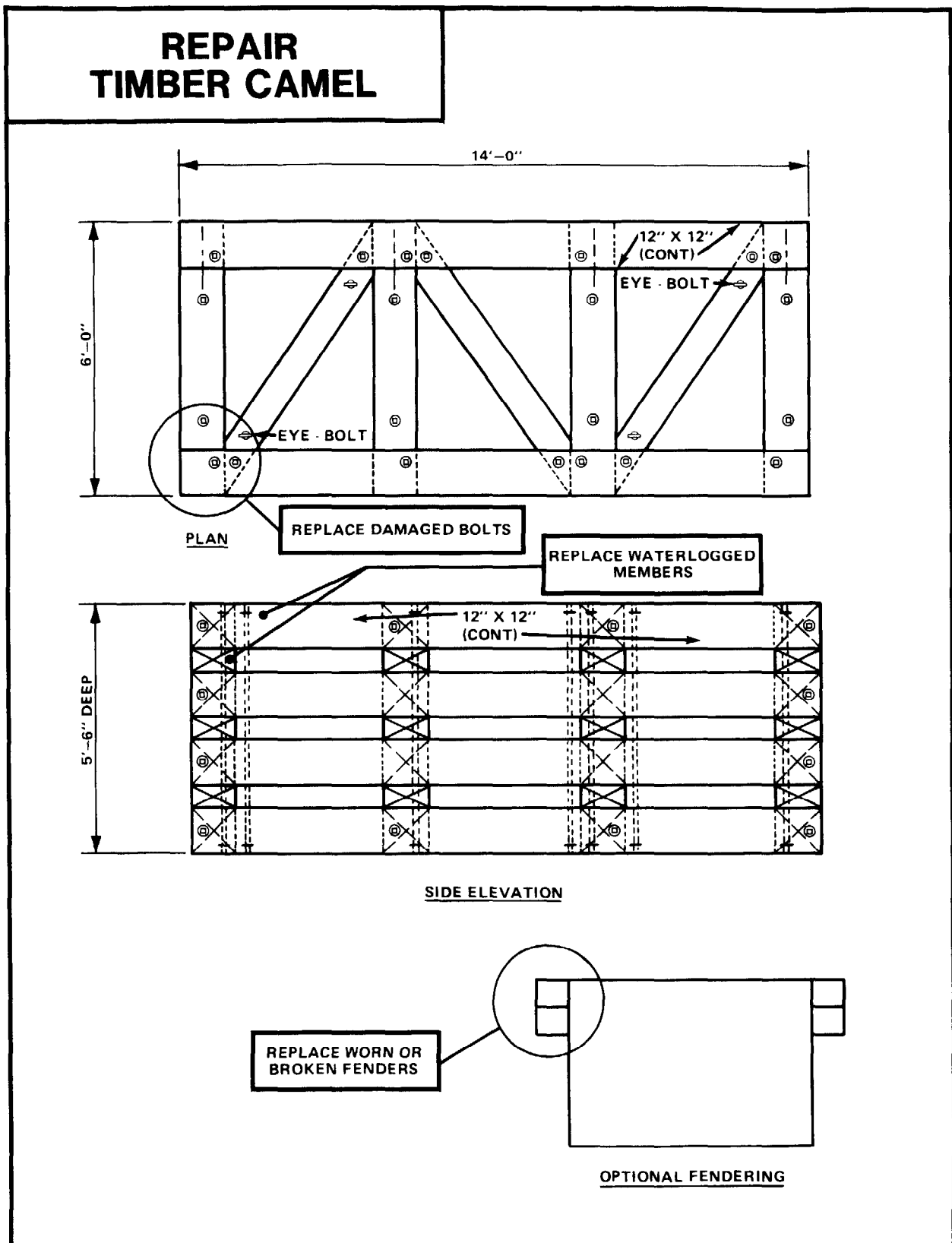


Figure 4-5. Typical Repairs to a Timber Camel.

**4.4 CONCRETE STRUCTURES.** Concrete, while being the predominant construction material used for waterfront structures, has had limited use in fender systems. Such usage has been primarily confined to concrete retaining walls and sheet piling used in wharfs and quaywalls. However, with current technology advances in the development and testing of prestressed concrete fender piles, it is anticipated that usage of concrete will grow considerably. Types of proposed configurations and uses are discussed in chapter 2. Other discussions of concrete use in waterfront structures, including piers and wharves, are contained in reference 1.

Deterioration of concrete near or in seawater can be due to improper mix and curing, excessive impacts and loads, severe weathering, chemical attack, and volume changes. Concrete available today is developed to resist deterioration and retain its durability over a long lifetime.

Concrete in waterfront facilities must meet the criteria set by the American Concrete Institute (ACI) Standard 318. Additional design information, covering prestressed concrete fender piles, is included in MIL-HDBK-1025/1 (reference 4), DM-25.06 (reference 5), reference 8, DM-2.04 (reference 16), and ACI Standards 211 and 212. These manuals and standards provide general design and application data for a variety of waterfront structures. A draft NAVFAC Guide Specification, providing specific guidelines for prestressed concrete fender piles, is available by contacting the Naval Civil Engineering Laboratory, Code L53. ASTM A 82, A 416, A 615, A 616 and A 617 provide standards for prestressed and conventional reinforcement for concrete.

**4.4.1 Preventive Maintenance for Concrete.** Most of the measures to prevent deterioration of prestressed concrete fender piles and panels must be taken during design of the concrete mix, design of the structure and prestressing requirements, and construction. Proper design for concrete is contained in ACI standards and service design manuals.

The main objectives of preventive maintenance for fender piles and panels involve:

- Keeping water out of the concrete.
- Protecting the reinforcing steel.
- Preventing excessive abrasion of the fender pile.
- Preventing and controlling cracking.
- Preventing chemical actions.

The primary PM measures that should be continually taken are surface coatings for concrete, treatment of cracks, and the use of rub strips when wood or steel camels are placed against the fenders.

**4.4.1.1 Surface Coatings for Concrete** Concrete structures that are periodically or continuously immersed in seawater or subject to seawater splash are seldom painted except for marking identification or location. One exception involves using surface coatings to seal small cracks.

**a. Surface Preparation.** Patching, caulking, and other repairs must be made to concrete structures before the surface is prepared for coating. Any efflorescence or laitance (white to gray powdery deposits from the concrete interior) is first removed with a clean, dry wire or stiff bristle brush. The surface is then scrubbed with a 5 to 10 percent solution of muriatic (hydrochloric) acid, rinsed with fresh water, and allowed to dry. Any grease or oil is then removed by solvent cleaning as described in SSPC SP-1. This can usually best be accomplished by using rags soaked with mineral spirits. Then, the concrete is carefully waterblasted or sandblasted to remove dirt and old coatings. Coatings in good condition and adhering freely to the surface may be allowed to remain, if they are compatible with the coating system to be applied; that is, if they are of the same generic type. Any residual dust from blasting must be removed by brushing or blowing with clean, dry air before application of coatings.

**b. Recommended Coatings.** The standard specifications for coatings recommended in this paragraph are listed in appendix A. If the concrete is to be sealed against moisture penetration, two coats of chlorinated rubber (TT-P-95, Type 1) or epoxy polyamide (MIL-P-24441) are recommended. The epoxy polyamide will chalk freely in direct sunlight. If this is undesirable, a topcoat of aliphatic polyurethane (MIL-C-83286) should be used to resist exterior weathering. If the concrete surface has slight irregularities, such as fine cracks that are unsightly, a textured coating (TT-C-555) may relieve the problem while sealing the surface. It is applied in one or two coats over a compatible primer to give a total of about 20 mils dry film thickness.

If the concrete is not to be sealed, but an appearance finish is desired, two coats of acrylic latex paint (TT-P-19) are recommended.

All of these coatings, except the textured coating, are easily applied by brush, roller, or spray. Brushing of the first coat onto the concrete will result in better penetration and coverage. The textured coating may require special spray equipment or other special procedures, so the manufacturer's instructions should be followed carefully. The manufacturer's recommended primer should also be used to ensure compatibility with substrate and textured coating. Latex acrylic paint (TT-P-19) should be applied as a topcoat to weathered textured coating when a more pleasing appearance is desired.

**4.4.1.2 Treatment of Cracks.** Sealing and caulking of cracks that require no cutting or extraordinary routing is considered a part of preventive maintenance. The very small cracks measuring less than 0.011 inch in width, will be filled or spanned by surface coatings discussed in paragraph 4.4.1.1. Other small cracks resulting from manufacturing processes, curing, or installation may be filled/caulked in preparation for surface coating and to keep water out of the concrete. Filling may be by injection of a low-viscosity epoxy resin and epoxy sealant, or other quality commercial products suitable to the application. Routing and cleaning the crack to prepare a good bonding surface for the sealer is the most important step in treatment of cracks.

**4.4.1.3 Rub Strips.** Rub strips can be installed on the outward face of the fender piles to prevent abrasion damage from vessel or camel impact and vice versa. These rub strips will extend from the top of the pile to approximately 3 feet below extreme low water.

Rub strips may be constructed of treated Douglas fir, rubber, or ultra-high molecular weight (UHMW) plastic. In each application, the type of ship loading must be seriously considered. For light vessels and small craft, timber or rubber fender strips may suffice. For larger surface combatants and service ships, UHMW rub strips will probably be required.

Installation of timber or UHMW rub strips should be accomplished by bolting the rub strip down the center through the pile as shown in figure 4-6. A steel pipe sleeved hole is recommended in the pile in order to carry the stress around the hole on the compression face, thereby maintaining the structural capacity of the pile. Galvanized pipe sleeves are used in the pile to allow easy removal, and replacement of the strip should it be damaged.

Attachment of a rubber rub strip to the pile would normally be accomplished using either anchor bolts or machine bolts/stainless steel sleeves down each side of the rubber fender.

**4.4.1.4 Timber Jackets.** Timber jackets, similar to the application shown in figure 4-7, may be used on prestressed concrete fender piles in order to provide additional protection against the abrasive action of ice in northern climates. Reference 5 contains additional information with a photograph of a case where the life of structural piling was extended significantly by such a jacket. The use of the timber jacketing would be restricted to fender piling used in conjunction with concrete bearing panels. Two-inch lumber, with galvanic steel bands, are used with the jacket extending the length of the tidal zone.

#### 4.4.2 Repairs to Concrete Fender Piling.

Repair methods for concrete fender pile systems are generally directed at replacing rub strips, sealing cracks and patching spalled areas in the pre-stressed concrete piles and panels, and replacing damaged or missing hardware connectors. Other repair requirements may include entire replacement of concrete fender piles and/or panel sections.

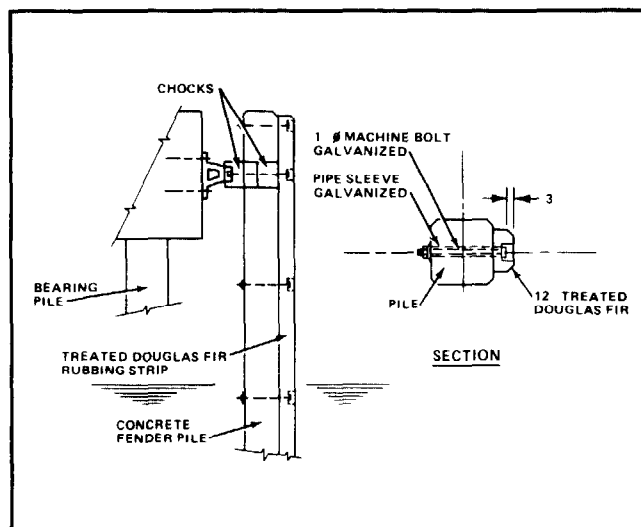


Figure 4-6. Rub Strip on a Concrete Fender Pile

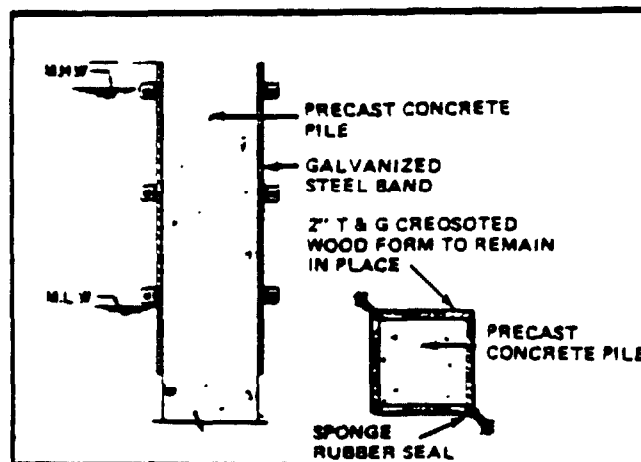


Figure 4-7. Timber Jacket On a Concrete Pile

Quality concrete used in the original fendering design or in fabrication of replacement piles and panels is the major means of providing a durable product. To obtain quality products for use in fendering systems, the following elements should be emphasized in the design:

**a. Surface Preparation.** All deteriorated concrete must be removed down to sound concrete. For some old concretes, exposed surfaces will soften after a few days of exposure; therefore, the surfaces should be checked closely before final patching operations. Clean the old surface thoroughly just before placing new concrete.

Normally, concrete removal is performed with hand tools or light duty hand-held power tools, particularly around the edges, to prevent damage to the remaining concrete. Edges should be square, preferably cut by sawing to about a 1-inch depth. Feathered edges must be absolutely avoided. Inside corners of a cavity should be rounded to a 1-inch radius. Reinforcing bars should be exposed around their entire circumference by a clearance of 1 inch.

Sandblasting surfaces removes loose concrete fragments and scaling rust from steel. Once the steel is clean, it can be protected by coating with a slurry of portland cement grout or latex modified portland cement grout. This procedure improves the life of the repair.

**b. Bonding.** Before patching, the existing base concrete should be kept damp (except for epoxy concrete repair) for several hours, preferably overnight. Remove free water or shiny wet areas by vacuuming or with oil-free compressed air. A bonding agent should then be scrubbed into the surface. The bonding agent can be portland cement slurry or mortar, latex modified portland cement mortar, or epoxy resin. The mortars should be 1 part cement and 1 part sand passing the No 30 sieve, and have a consistency of thick cream. If an epoxy bonding agent is used, follow the manufacturer's recommendations precisely. In all cases, it is important to place the repair concrete before the bonding agent dries.

**c. Curing.** Concrete used in repairs must be protected and cured more carefully than usual. The old concrete could absorb moisture too rapidly from the new concrete, or the temperature of the old concrete could be too low to permit early development of strength of a concrete patch.

Curing is important to allow strength development and prevent drying shrinkage. For portland cement mixes, water curing by ponding with water, fog misting, or covering with wet burlap are the best methods. Other acceptable methods include covering with plastic sheeting material or coating with curing compound. The repair concrete should be kept wet or moist for a minimum of 7 days. When water evaporates from the concrete, drying shrinkage occurs. Shrinkage of a patch can cause the patch to crack or partially debond.

It is important in curing epoxy concrete to provide the correct temperature for the epoxy resin to develop full strength. Epoxy resins that use 100 percent solids and no solvents do not shrink. Epoxy resins do, however, have a much greater coefficient of expansion than concrete. This can lead to failure in large patches and in environments that experience large temperature

## GUIDELINES FOR FABRICATION OF PRESTRESSED CONCRETE PILES AND BEARING PANELS

- Design guidance for prestressed concrete fender piles is contained in reference 8.
- Use 6000 psi concrete or greater for prestressed concrete members.
- Use **only** Type II cement conforming to ASTM C 150, with a tricalcium aluminate (C<sub>3</sub>A) content between 6% and 10% for good sulfate resistance. Alkalies such as Na<sub>2</sub>O shall be less than 0.60.
- Use a minimum of 650 lbs to a maximum of 850 lbs of cement per cubic yard of high strength concrete.
- Use a maximum water-cement ratio of 0.40 by weight.
- Use mineral aggregate no larger than 3/4 inch, conforming to ASTM C 33.
- Make sure concrete cover over reinforcing steel is at least 2 inches.
- Use seven-wire prestressed steel conforming to ASTM A 416.
- Use supporting reinforcement conforming to ASTM A 615, A 616, or A 617, Grade 60, deformed reinforcing bars.
- Provide adequate vibration of the concrete mix.
- Control the curing to prevent the ambient temperature in contact with the pile from falling more than 40°F below the concrete temperature.
- Give particular consideration to the use of admixtures:
  - Use Type A or D water-reducing admixture conforming to ASTM C 494.
  - Use fly ash or silica fume conforming to ASTM C 618, to improve durability.
  - For concrete subject to freeze-thaw cycles, use air-entraining conforming to ASTM C 260 to obtain 5 to 8 percent air content.
  - **Do not** use any admixture containing chloride.

To obtain quality concrete repairs, the following basics are mandatory for all jobs:

- **Properly prepare the surface** of the old concrete to be adjoined.
  - Ensure a **good bond** between the old and new concrete.
  - **Do not add** more water than specified for the concrete mix.
  - **Do not patch** across active cracks or joints.
  - **Cure** the concrete properly.

differentials between day and night. Epoxy can be mixed with sand (1 part epoxy: 7 parts sand) to minimize the difference in the thermal expansion characteristics.

#### d. Special Types of Repair Concrete.

- **Fiber-reinforced Concrete.** Concrete and mortar containing fibers of steel, glass or polypropylene are sometimes used in repair work. Fiber reinforcement provides improved tensile strength, toughness and ductility to concrete. The fibers reinforce crack repair material by distributing tensile strains.
- **Latex Modified Portland Cement Concrete.** Latex modified portland cement concrete should not be confused with epoxy or polymer concrete. Latex modifiers improve the bond and tensile strength and reduce the permeability of portland cement concrete. Latex formulations of acrylics, styrenebutadiene, and polyvinyl acetates are available. The first two latexes are suitable for wet environments. Polyvinyl acetates should not be used in concrete for repairs exposed to water. The mix and application of this type may be difficult to control in the field.
- **Epoxy Concrete.** Epoxy concrete does not contain portland cement. It is a mixture of an epoxy resin and aggregate. Epoxy concrete is the most popular type of polymer concrete because of its flexibility in use, good adhesion, and availability. Other commercially available polymers are acrylics, polyesters, polyurethanes, and polyvinyl acetate. Epoxy resin, when mixed with a curing agent, forms a thermosetting plastic that rapidly develops adhesive strength. Epoxy mixes are used for several purposes: to repair cracks by injecting the resin, to bond repair material to the base concrete by brushing on the resin, and to make epoxy mortar or concrete by mixing the resin with fine and coarse aggregate. Because the cost is relatively high and the material is relatively inflexible in thick layers, epoxy concrete is used mainly for thin section repairs. Epoxy with a low modulus of elasticity should be used to minimize thermal expansion problems. Proprietary, prepackaged systems should be used.

See Chapter 7 and repair techniques CR-4 and CR-7 in reference 1.

**4.4.2.1 Planning the Repair.** The initial planning step must involve review of prior inspection reports in order to determine the scope of deterioration, the rate of deterioration, and specific operational constraints placed upon the facilities because of the deterioration. Because the prestressed concrete fender piles often maintain considerable strength even though damaged, pile replacement may be accomplished in a planned program versus a reactive approach. This includes using economic analyses as one tool in the planning process. Once the scope of repair requirements, including priorities, are established, the method of accomplishment, whether in-house or by contract, must be determined.

Repairs to concrete fender systems will normally be limited to sealing small sized cracks, patching small to medium sized spalled areas, and replacement of damaged members. The skills and equipment requirements will depend

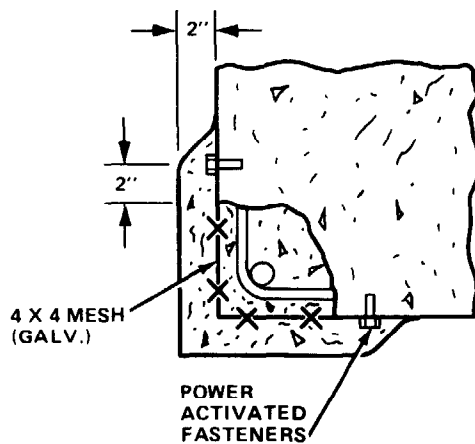
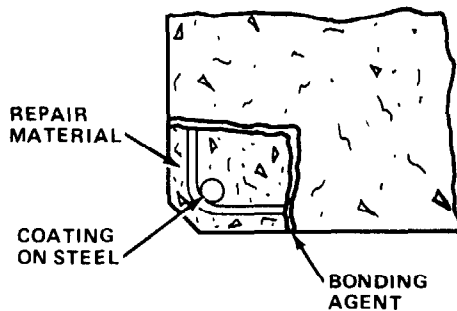
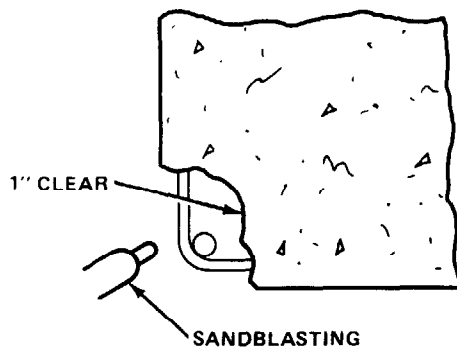
upon the extent of repairs. For most sealing and patching requirements above water, normal skills associated with the concrete construction trade will be adequate. For fabrication of prestressed concrete members, special skills and equipment are required that may be obtained from a qualified vendor.

Underwater repairs can require special skills such as knowledge and experience in removal of marine growth, underwater jetting and blasting, use of underwater tools for cutting and drilling, and the use of certain materials for coating and caulking underwater. Unique equipment requirements may also exist on underwater repairs that will dictate the personnel skill requirements. See reference 1 for more detailed discussion of concrete placement methods and underwater repairs.

**4.4.2.2 Repair Procedures for Concrete Fender Systems.** Figure 4-8 summarizes general steps to be used in most concrete repairs. Typical repair procedures include:

- Repairs to small cracks by epoxy grout injection.
- Repair of spalled areas.
- Replacement of damaged concrete members.

# REPAIR CONCRETE STRUCTURES



**ALTERNATE SECTION**

## SURFACE PREPARATION

- Remove all deteriorated and loose concrete.
- Expose all uncovered reinforcing steel at least 1 inch clear all around.
- Sandblast/waterblast/wire brush concrete and steel as necessary to clean thoroughly.
- Keep concrete surface wet for several hours.
- Replace sections of reinforcing steel as required.
- Coat reinforcing steel with grout or epoxy resin.
- Just before placing repair material, apply bonding agent to old concrete.

## PLACE REPAIR MATERIAL

- Bonding agent must be wet or tacky.
- Depending on size and type of repair, material may be a mortar or concrete; portland cement concrete, latex modified concrete, or epoxy concrete.
- Above water placement; hand placement, dry pack, cast-in-place, or shotcrete.
- Underwater placement; tremie, pumped, or prepacked. See reference 1 for description.

## CURING

- Use most efficient moist-curing for minimum of 7 days if practicable.
- Use curing compound if necessary.

## SURFACE COATING

- Determine if surface coating is required.
- Prepare surface by air/abrasive blasting.
- Apply coating applicable to location, exposure, and use of concrete.

Figure 4-8. General Steps to Concrete Repair.

## REPAIR SMALL TO MEDIUM CRACKS BY EPOXY GROUT INJECTION

**Problem:** Cracks caused by manufacturing, installation, weathering, deterioration, or reinforcing steel corrosion allow water to penetrate the structure.

**Description of Repairs:** Filling and sealing small cracks by injecting a low-viscosity epoxy resin and sealing the outside with an epoxy paste. Routing and cleaning of cracks are performed with conventional hand and power tools. Injection of the epoxy for smaller jobs can be done with a hand-operated caulking gun. Large jobs are usually done with special epoxy pumps, operating at less than 150 psi, with mixing tank, injection hose, and controls.

**Materials:**

- a. Low-Viscosity Epoxy - Select an epoxy resin conforming to ASTM C 881, suitable for wet surfaces and underwater application that is compatible with crack volume, the existing concrete, and equipment to be used for injection.
- b. Sealing Epoxy - Use a quick-setting epoxy paste adhesive suitable for underwater application that has good bonding characteristics for concrete being repaired.

**Preparation.**

- a. Rout out cracks to remove all deteriorated and loose concrete and aggregate. Clean area to receive sealing epoxy with wire brush, high pressure water jet, or sandblasting.
- b. For small and shallow cracks to be repaired with a handgun, injection ports may be simply openings left in the sealing epoxy every 6 inches.

**Repair Procedures:** See figure 4-9.

- a. Perform repairs when ambient/water temperature is at least 50°F.
- b. Seal the outside surface of the crack with the epoxy paste, carefully sealing around the injection ports.
- c. After the surface seal has set, the low-viscosity epoxy grout is injected, starting at the bottom port for a vertical crack. Continue injection until epoxy shows in the next port, then continue up the crack until the entire crack is filled.
- d. Plug the port holes with the sealing epoxy paste.

## REPAIR CONCRETE CRACKS

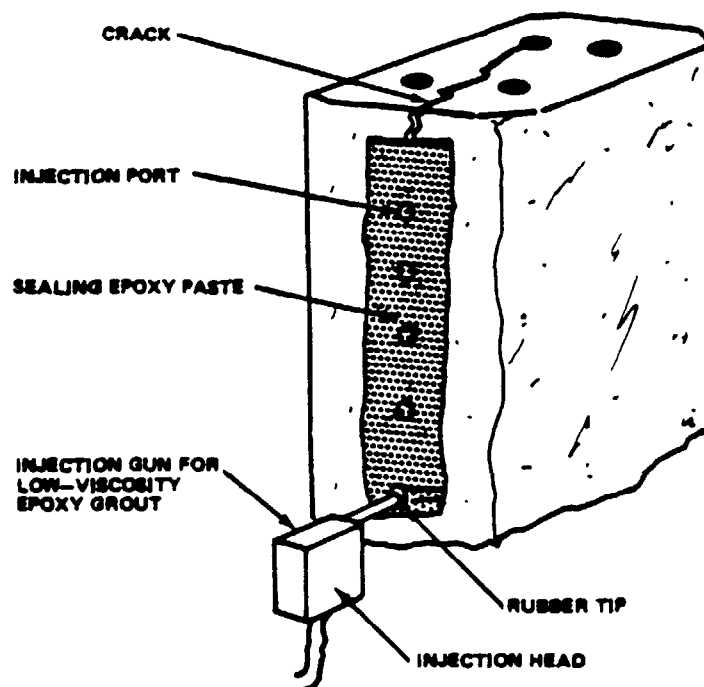


Figure 4-9. Typical Crack Repair with Epoxy Grout Injection.

## REPAIRS TO SPALLED AREAS ON CONCRETE PILES

**Problem:** Concrete pile is worn from abrasion at waterline or has spalled areas above the tidal zone.

**Description of Repairs:** In all cases, the repair area must be cleaned thoroughly of marine growth. All loose and deteriorated concrete must be removed. If reinforcing steel is exposed, it must be cleaned of all rust and scale and exposed at least 1 inch clear all around. Epoxy coat reinforcing steel if above mean low water.

The following procedures will normally be followed in repairing spalled areas (figure 4-10):

**Bonding:** Brush coat repair area with cement grout: Type II cement and enough water for a slurry consistency.

**Mortar Mix:** The proportions of the mix will depend upon the overall size and depth of the repair, accessibility, and whether the repair is large enough to require coarse aggregate. A typical cement-to-sand ratio is 1:2.5 to 1:3. The water-cement ratio should be no greater than 0.40.

**Placement:**

- a. If repair is in direct sun or wind, erect shade/wind break and leave in place during curing period.
- b. Wet surface of repair area. Do not leave any free water.
- c. Coat surface of the repair area with bonding grout with a brush.
- d. Immediately trowel on mortar mixture ensuring complete filling of voids and dense placement.

**Curing:** Use a curing compound or wet burlap.

**Applications:** Replace the pile if extensive spalling has occurred. The spall patching and crack filling repairs are relatively minor, inexpensive techniques to protect the reinforcing steel from seawater. The effectiveness of the spall patches is dependent upon the bond that is obtained with the old concrete.

## REPAIR CONCRETE PILES

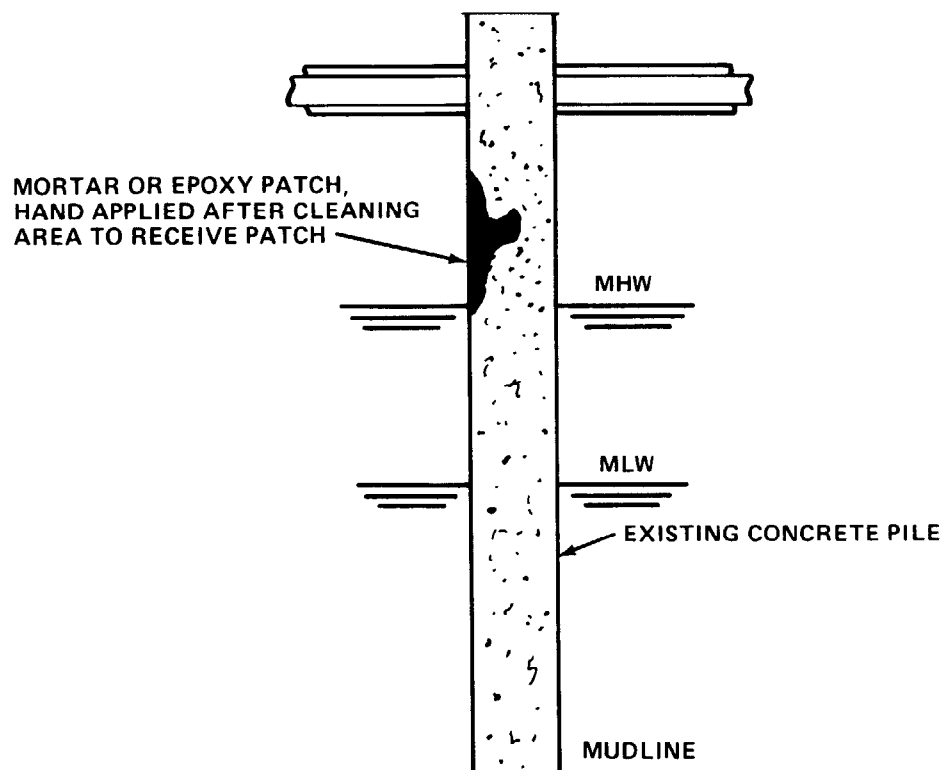


Figure 4-10. Repairs to Spalled Areas on Concrete Piling.

## REPLACING CONCRETE FENDER PILING

**Problem** Fender piles and/or panels are seriously damaged or missing.

**Description of Repair:** Remove damaged piles, wales, chocks, and hardware. Drive new prestressed concrete piles aligning the elevation of the tops to match the existing system. Install new wales, chocks, rubbing strips, and/or rubber fenders to match existing (figure 4-11). Install galvanized bolts and other support hardware.

Fabrication of all prestressed concrete piles should conform to the guidelines outlined earlier in the chapter. Repairs to the pier structure and nonprestressed concrete members should conform to the guidelines outlined in reference 1.

Special care should be exercised in the handling of all concrete piling in order to prevent damage to the members. Take care to avoid damage to the piles during handling, placing the pile in the leads, and during the pile driving operations. Laterally support piles during driving, but do not unduly restrain from rotation in the leads. Where pile or reinforcement orientation is essential, take special care to maintain the orientation during driving. (Take special care in supporting battered piles to prevent excessive bending stresses in the pile). Square the top of the pile to the longitudinal axis of the pile. Use a steel driving helmet or cap including a pile cushion between the top of the pile and the driving helmet or cap to prevent impact damage to the pile.

**Application:** Replacement of concrete fender piles should normally be pursued in lieu of major repairs to existing members. Careful attention should be given to the history of damage to the area in question, before repairs are made. If the frequency of damage is high, an alternate fendering system should be considered.

**Future Inspection Requirements:** Close monitoring of fender performance will be required to document the rate and frequency of damage. Level I inspections every 3 months may be required if accelerated wear or damage is noted. Good documentation of maintenance/repair history is essential.

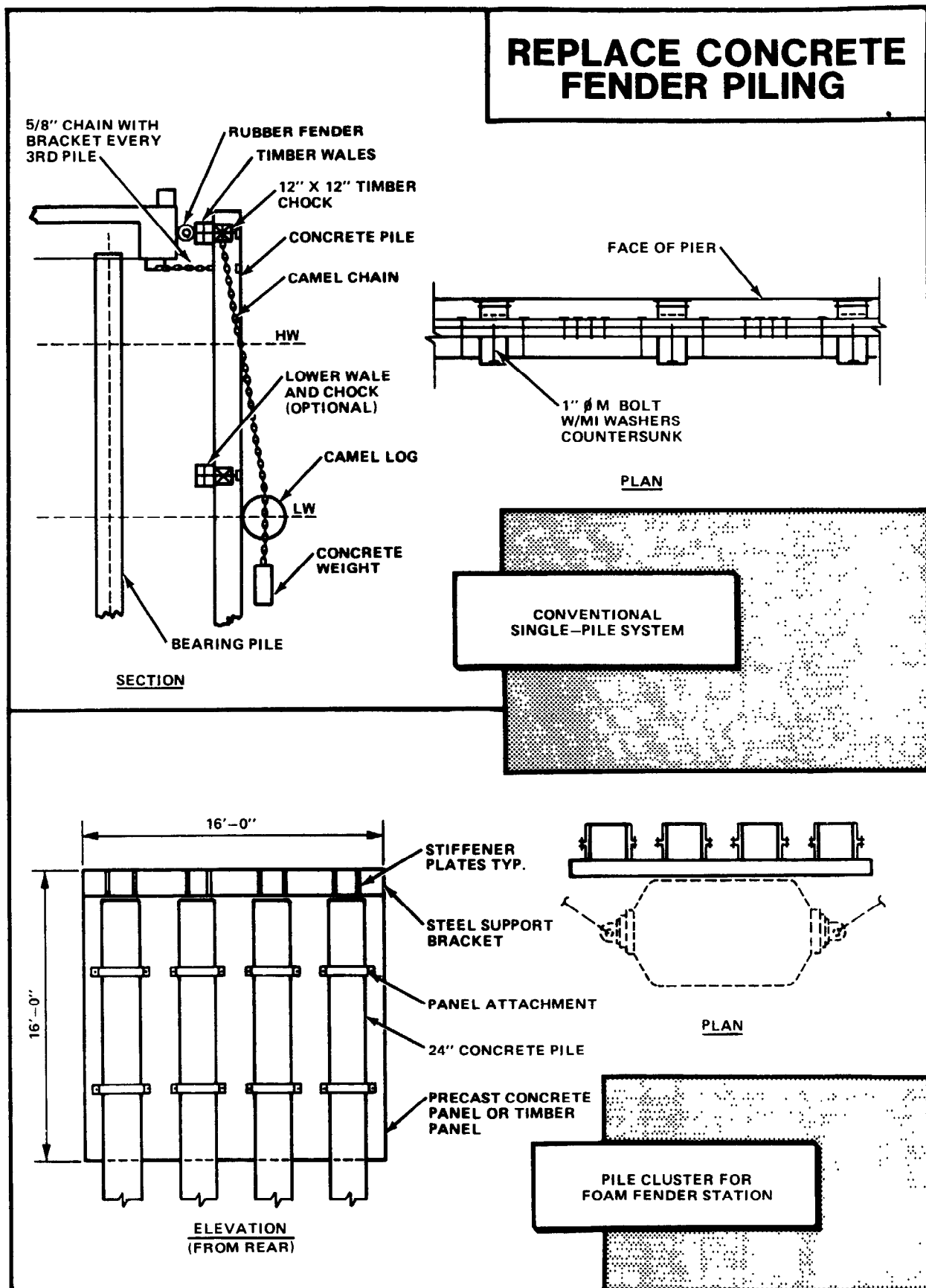


Figure 4-11. Example Designs for Replacement of Concrete Fender Pile Systems

**4.5 STEEL STRUCTURES.** Steel is used in the waterfront environment for fender systems and camels due to availability, cost, ease of fabrication, physical and mechanical properties, and design experience with its use. Typical applications include:

- Steel H-pile fender systems.
- Steel H-piles with timber wales, chocks and rubbing strips.
- Steel angles used with timber and concrete fender systems.
- Steel framed shallow draft camels for aircraft carriers and deep draft camels for submarines.
- Steel framed separators for submarines.
- Hardware including bolts, nuts and chains used with timber and concrete fender piling, and timber camels.

Other uses of steel for bearing and sheet piling are discussed in reference 1.

Maintenance of steel structures and components will entail repair or replacement of damaged or corroded steel, periodic coating of steel surfaces for corrosion protection, and maintenance of cathodic protection systems. Corrosion is the major cause of the deterioration of steel structures. The extent or severity of corrosion will vary with the exposure zone of the material; that is, whether it is in the atmospheric zone, the splash or tidal zone, or the submerged zone. The selection of materials for waterfront use must consider each of these varied conditions.

The use of steel should follow design guidelines in NAVFAC Design Manuals, references 5 and 17, and the American Institute of Steel Construction's Manual of Steel Construction. The material specifications of ASTM, the American Society for Metals, and other organizations document chemical and physical characteristics of the various types of steel. Material selection and procurement should conform to these specifications.

Carbon steel and carbon steel alloys are the most important types of metals used for construction of waterfront facilities. In general, only low carbon steels with a carbon content less than 0.35 percent by weight are used due to welding characteristics. Except for physical damage from impact or loading, deterioration of steel is caused only by corrosion.

Carbon steel is an alloy of iron and carbon with a carbon content less than 2 percent. The requirements for structural carbon steel are contained in ASTM A 36 and this grade is suitable for welding. The requirements for welding are contained in AWS D1.1. All machine bolts shall conform to ASTM A 307. High strength bolts shall conform to ASTM A 325.

Carbon steel will corrode in all exposure zones, but the severest corrosion occurs in the splash zone and just below mean low water. Coatings or

cathodic protection, or a combination of the two, are necessary to prevent excessive corrosion of steel in the waterfront environment. Coatings are covered in paragraph 4.5.1.1. Cathodic protection is covered in paragraph 4.5.1.2.

Corrosion resistant, low-alloy carbon steel may be used instead of carbon steel if greater corrosion resistance is required. Low-alloy carbon steels contain small amounts of other elements such as copper, chromium, nickel, molybdenum, silicon and manganese. Up to 1.5 percent of these elements is added for increased strength or heat treatment capability. These alloys have a better resistance to corrosion because the rust does not easily break away from the metal surface. The life of a low-alloy steel may be five times as great as carbon steel.

The common low-alloy steels include ASTM A 690 (also called "Mariner steel"), A 588, A 572, and A 242. Steel conforming to ASTM A 690 is recommended for steel H-piles and camel framing, because of its greater corrosion resistance over plain carbon steel in the splash zone. When submerged, however, the low alloy steels offer no more resistance to corrosion than ordinary carbon steel, and the low alloy steels require coatings or cathodic protection, or both. Composite piles of A 690 and A 36 may be utilized when greater resistance in the splash zone is required. ASTM A 588 and A 242 steels are not recommended for buried structures, submerged conditions, and marine atmospheres unless they are exposed to the wind, rain, and sun.

Coatings for, and cathodic protection of, low-alloy carbon steels, are the same as for plain carbon steel as discussed in section 4.5.1.

**4.5.1 Preventive Maintenance for Steel.** The primary preventive measures to increase the life of steel are protective coatings and cathodic protection. The decision of which approach to use is a function of location on the waterfront structure (submerged or not) and economics. The use of cathodic protection is restricted to submerged or buried structures. NAVFAC MO-306 (reference 11) provides general guidelines for corrosion prevention and control for steel structures. This manual is being updated for issue in 1990.

**4.5.1.1 Protective Coatings for Steel.** The basic method of protecting steel from corrosion is by coating. Coatings should be free of pinholes or discontinuities to control corrosion of the underlying steel. A corrosion inhibitive pigment should be used to prevent corrosion if a break in the coating develops. Reference 12 provides a comprehensive coverage of protective coatings for steel structures.

Since unprotected steel corrodes freely and often severely in a marine environment, it is almost always coated. Sometimes, underwater portions of steel piling to receive cathodic protection are not coated. While coating of such areas is recommended, a combination of cathodic protection and coating is usually the most cost effective in the long term. Steel components of waterfront structures are best shop-coated, transported to the job site, and spot repaired, if necessary, before installation.

**a. Surface Preparation.** Irregular steel surfaces, such as welds and sharp edges, should be ground smooth before preparing the surface for coating. The steel should then be cleaned by abrasive blasting and coated as soon as possible. A high level of blast cleaning is required for coating with a high performance coating, such as epoxy or coal tar epoxy. Lower performance coatings or less severe environments require a lower level of surface preparation. Recommendations for the various levels of cleanliness as defined by SSPC are as follows (see appendix A):

Coating System	Immersed, Splash, or Tidal Area	Less Severe Areas Above Water
Alkyd	Not recommended	SSPC SP-10 or SP-6
Coal Tar	Not recommended	SSPC SP-6
Epoxy	SSPC SP-5 or 10	SSPC SP-10
Coal Tar Epoxy	SSPC SP-5 or 10	SSPC SP-10

**b. Recommended Coatings.** See appendix A for titles of specifications referenced. Epoxy polyamide (three coats of MIL-P-24441) or coal tar epoxy polyamide (two coats of SSPC Paint No. 16 or Corps of Engineers C-200) are recommended for piling and other steel structures which are to be immersed in seawater. Coal tar epoxies become brittle from prolonged exposure in direct sunlight, and are not recommended for this exposure. Epoxies perform well in direct sunlight except for chalking. If chalking is objectionable, substitute a coat of aliphatic polyurethane (MIL-C-83286) for the third coat of epoxy polyamide to obtain excellent weathering in direct sunlight.

For milder atmospheric exposures, an alkyd system (one coat of TT-P-645 primer and two topcoats of TT-E-490) will provide adequate protection.

Coal tar coatings (MIL-C-18480) are occasionally used for temporary protection over marginally prepared surfaces. They provide good temporary protection until a more permanent coating system can be applied. They may also be used as a dip coating for components such as chain that are difficult to coat otherwise.

All of the above coatings can be applied by brush, roller, or spray. Brushing of the prime coats onto the steel will achieve better surface penetration. Adjacent coats should be applied on successive days. Instructions for application of MIL-P-24441 can be found in Chapter 631 of Naval Ships' Technical Manual NAVSEA S9086-VD-STM-000 (reference 18). Instructions for applying SSPC Paint No 16 can be found in Steel Structures Painting Manual Vol 2, Systems and Specifications (reference 19).

**4.5.1.2 Cathodic Protection of Steel.** The natural corrosion of steel structures immersed in water or buried in soil can effectively be controlled by the use

of cathodic protection systems to minimize or stop the corrosion process, by establishing the steel as a cathode. Cathodic protection systems are best installed when the structure is constructed, but can be added to existing structures. They can effectively stop corrosion but cannot restore the material already lost by corrosion. Design of cathodic protection systems is contained in reference 20. Maintenance of cathodic protection systems is covered in reference 13. Consideration must be given to potential interference with ship cathodic protection systems when utilizing this type of protection for fender systems.

**a. Galvanic Anode Systems.** Galvanic anode cathodic protection systems rely upon the corrosion of active metals such as zinc, magnesium or aluminum to generate the electrical current needed to protect buried or submerged steel structures. Since these anodes are sacrificed to protect the structure, they are known as sacrificial anodes. The anodes must be buried or submerged near the structure to be protected and electrically connected to it with a low resistance bond. As the anodes are consumed in providing protection, they must be periodically monitored and replaced when over 80 percent of the metal is consumed, or when they will be consumed before the next scheduled inspection. The level of protection provided can be determined by measuring the potential between the structure being protected compared to a standard reference electrode.

**b. Impressed Current Systems.** Impressed current cathodic protection systems use an external source of electrical alternating current, and a rectifier, to provide the protective direct current to be impressed across the system. This system also requires anodes buried or submerged in the vicinity of the structure being protected. These anodes can last much longer than galvanic anodes, since they only conduct the protective current into the water or soil and are not the source of the current. Impressed current cathodic protection systems also require periodic inspection and maintenance to ensure effectiveness in controlling corrosion.

#### **4.5.2 Repairs to Steel Fender Piles and Camels**

**4.5.2.1 Steel Fender Piles.** Corrosion is the major cause of deterioration of steel fender piling. The extent or severity of corrosion will vary with the exposure zone of the material; that is, whether it is in the atmospheric zone, the splash or tidal zone, or the submerged zone. Mechanical damage is second in major causes of deterioration or failure of steel fender piling. However, often mechanical failure is accelerated by corrosion of the structural steel members or welds and hardware connections. Generally in either case, repairs consist of total replacement of the piles, wales, chocks and connecting hardware. If corrosion is detected early enough, new protective coatings or cathodic protection may be applied to delay the rate of deterioration.

**4.5.2.2 Steel Framed Camels.** Repairs of steel framed camels include replacing damaged timber wearing strips, broken or loose welds and bolts, patching corroded or punctured flotation tanks, and replacing consumed cathodic protection anodes.

**4.5.2.3 Planning the Repair.** The initial planning step is review of prior inspection reports to determine the scope of damage and/or deterioration, the rate of deterioration, and specific operational constraints placed upon the facilities because of the deterioration. Once the scope of repair requirements, including priorities, is established, the type of replacement system and method of accomplishment may be determined. If the frequency and cost of repairs are high, an alternate fendering or camel system should be considered.

Skills and equipment requirements to perform the surface repairs are generally common to the activity's steelworker and wharfbuilder trades or local commercial capabilities.

Underwater repairs require special skill levels that may not be available within in-house forces. These include the general diving capability plus knowledge of: removal of marine growth; jetting or air lifting procedures; underwater cutting, welding and drilling techniques; underwater lifting procedures; application techniques for underwater protection coatings; techniques for underwater placement of epoxy mastic patches; and jacketing and wrapping materials used in underwater construction. Equipment for underwater repairs may include: high-pressure water blaster, hydraulic grinders with barnacle buster attachment, hydraulic drill and bits, hydraulic power unit, concrete pump with hose, jetting pump and hose, rigging equipment, float stage and scaffolding, cofferdams, clamping template for cutting piles, and special clamping equipment. See reference 1 for more detailed discussion of underwater repairs to steel structures.

**4.5.2.4 Repair Procedures.** Selection of a technique must address both immediate repairs necessary to restore the structure to full usage and protective measures needed to prevent further corrosion. Selection of means for restoring the structural capacity of the facility may be straightforward, being generally controlled by the level and rate of deterioration. Decisions on the level of protection to provide to inhibit corrosion in the future may be more difficult. Generally, these decisions are economically driven.

Each repair decision must carefully weigh the long term operational requirements and existing environmental factors (tides and currents) that can help accelerate corrosion prior to evaluating initial and life cycle costs. In many cases, including a combination of cathodic protection and protective coating in the repair decision may be the most cost effective in the long term. Use of any of the repair techniques which follow should fully adhere to the preservation treatment requirements outlined for steel structures in section 4.5.1.

After all members have been fastened or placed, bolt heads, washers, and nuts shall be given one full coat of petrolatum (grease) coating conforming to Federal Specification VV-P-236. All surfaces to be coated shall first be thoroughly cleaned and dried, and all nuts shall be drawn tight.

**a. Steel Fender Piles.** Repair procedures for steel fender pile systems include:

- Preventive measures involving coatings and cathodic protection.
- Installing a concrete cap and bearing surface on steel piling used on a wharf area.
- Replacing steel fender piles, wales, chocks, and hardware.

**b. Steel Framed Camels.** Repair procedures for steel framed camels include replacing damaged members and/or hardware, rewelding damaged joints and splices, patching corroded or punctured flotation tanks, and replacing consumed cathodic protection anodes.

## COATING/CATHODIC PROTECTION OF STEEL FENDER PILING

**Problem:** New steel piling has been installed or existing piling has experienced slight surface deterioration (less than 15 percent). Protection against further corrosion is required.

**Description of Repairs:** Three procedures may be followed in providing protection for steel fender piling (figure 4-12):

**Paint Coating:** Clean steel of all marine growth and loose rust using abrasive blasting equipment or water jetting equipment. Apply the paint coating following MIL-P-24441 guidelines.

**Epoxy-Polyamide Coating:** Clean steel above water with abrasive blasting equipment and underwater with water jet cleaning equipment. Mix epoxy and polyamide coating ingredients in ambient temperature of about 70°F. Apply epoxy coating by smearing by hand over steel surface to a thickness of 1/8 inch to 1/4 inch.

**Cathodic Protection:** For sacrificial anode system, place anodes below low water on steel by welding or bolting. Size, type and spacing of anodes must be determined to suit structure and environment. Positive electrical connection must be made. For an impressed current system, install the components as shown in figure 4-12.

**Application:** If water temperature is less than 60°F, proper bonding of the epoxy coating may not occur. Successful application requires a neutral or positive charge on the structure; negatively charged steel repels the negatively charged epoxy coating. Underwater application may be difficult. Prior to ordering the coating, a sample area of the surface to be coated should be tested under conditions identical to those in which the project will be carried out to be sure that the coating will adhere properly.

The cathodic protection system requires careful design and installation. In addition, the system is not effective for mitigating corrosion above mean low water.

**Future Inspection Requirement:** Increased inspection may be required, particularly in areas where ice may be present, in order to detect signs of abrasion of the mastic or removal of the anodes, and renewed corrosion of the fender piling.

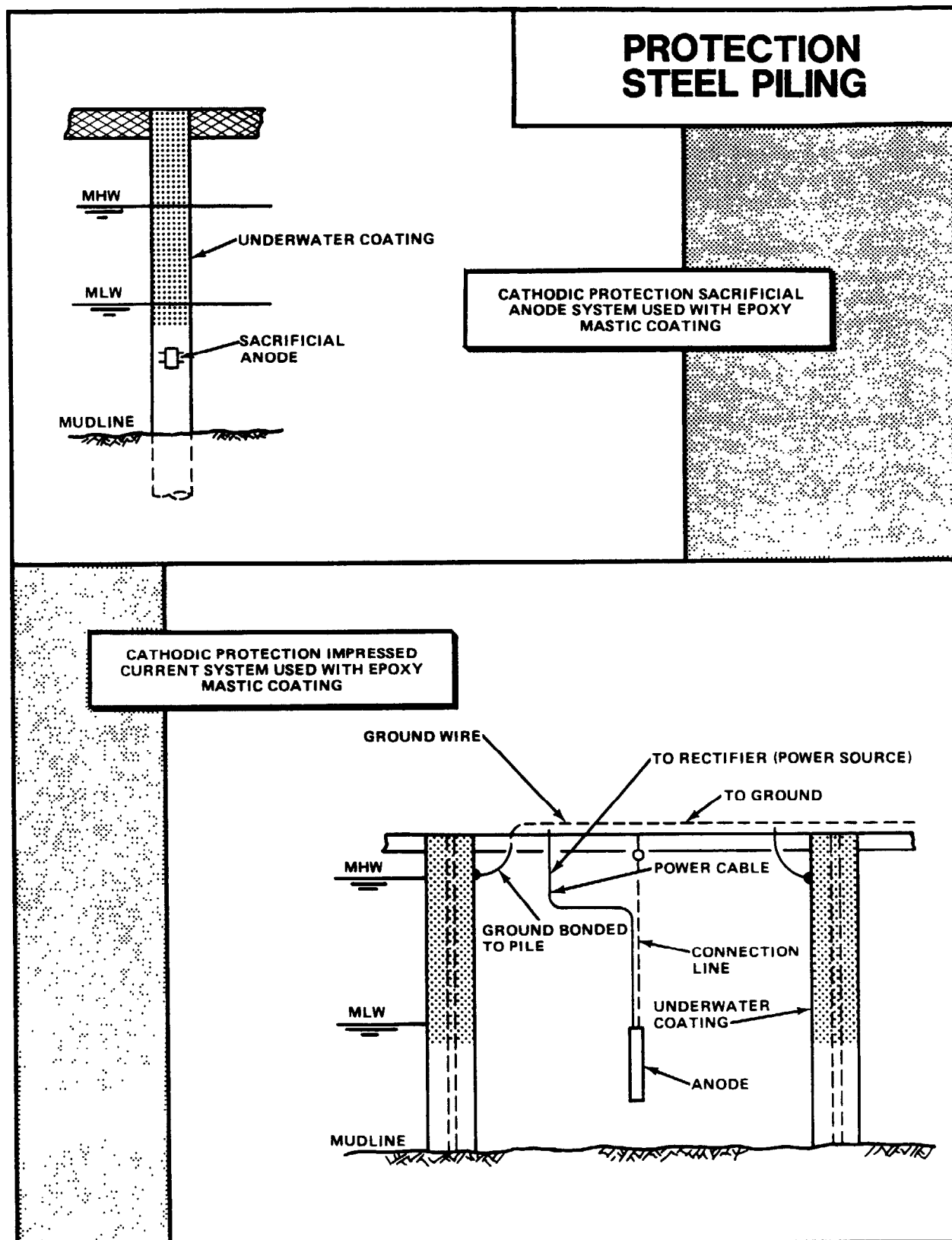


Figure 4-12. Coating and Cathodic Protection for Steel Fender Piles.

## INSTALLING A CONCRETE CAP/BEARING SURFACE ON STEEL PILING USED ON A WHARF

**Problem:** Advanced deterioration of the steel and/or steel sheet pile structure is starting to occur on a wharf. The steel still has good structural integrity.

**Description of Repairs:** Excavate the soil from behind the wall to a level required for the new concrete cap and attachment of form ties for a concrete face. Remove all marine growth and deteriorated steel, and clean surfaces.

Build forms, place reinforcing for the cap. Place and fasten blocking and low wale against existing sheet piling for the concrete face. Drive the timber sheet pile wall about one foot in front of existing sheet piling using wale as guide. Attach outside wales to timber sheeting, install reinforcing and place concrete by pumping or tremie. Remove timber sheet piling (figure 4-13).

**Application:** Used to restore structural strength at the top of the wall (cap) or prevent further loss of soil through holes in the sheet piling (face), while providing a bearing surface for foam-filled fenders. Does not restore bending moment capacity in wall that has been lost. Provides protection against further deterioration.

**Future Inspection Requirements:** Careful inspection should be made annually of the sheet piling areas immediately under the pile cap in order to ensure that further corrosive damage is not being experienced, thereby significantly weakening the support for the concrete cap and partial concrete faces. For complete concrete facing, normal inspection procedures should be followed.

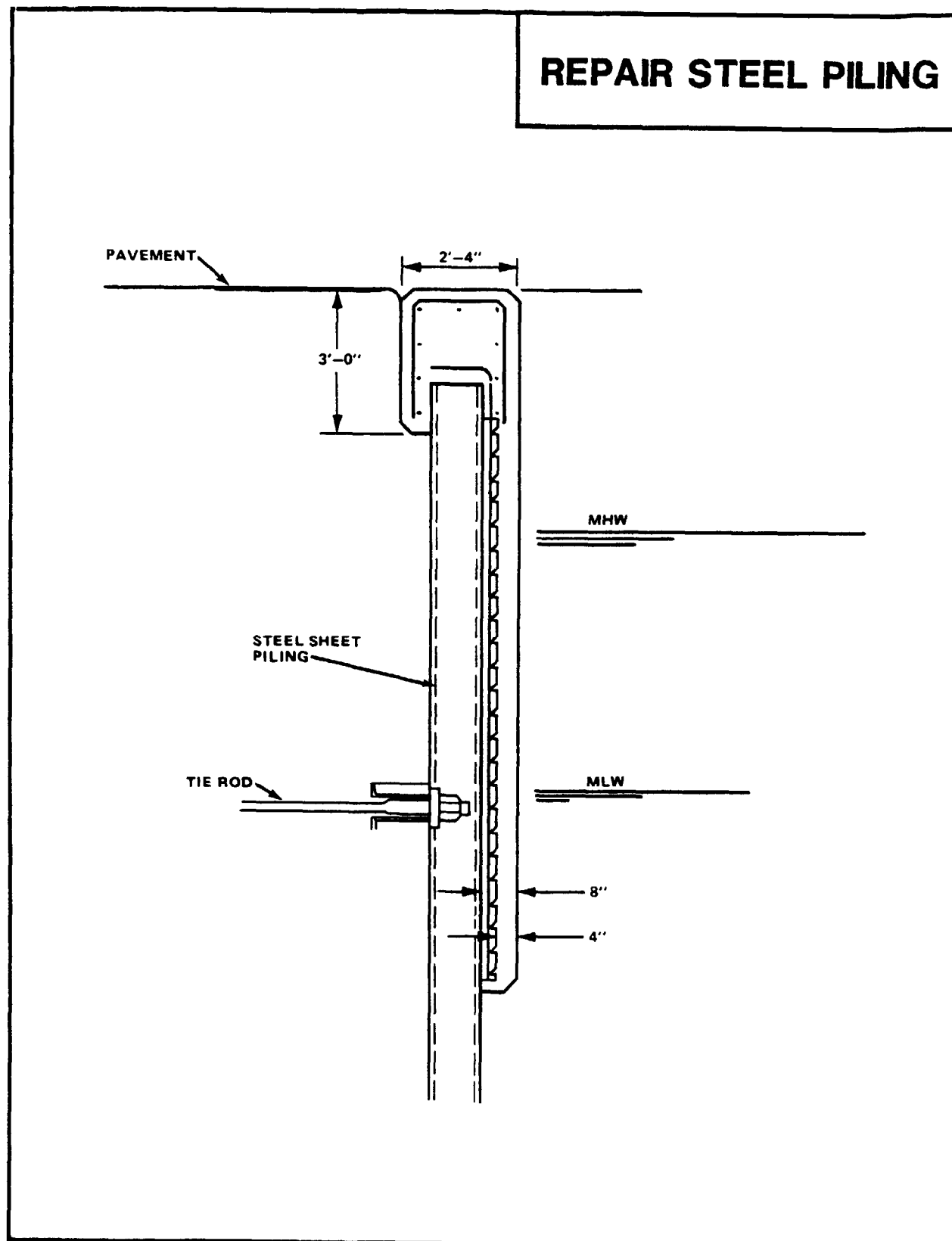


Figure 4-13. Installing a Concrete Cap and Face on a Steel Sheet Piling Wall.

## COMPLETE REPLACEMENT OF STEEL FENDER PILING

**Problem:** Moderate to heavy deterioration (greater than 35 percent) of the cross-sectional area, or damage, has occurred to a steel H-pile fender and/or support hardware.

**Description of Repairs:** Remove damaged pile, wales, chocks and hardware. Drive a new pile cut to match the elevation of the adjacent steel piling. Install new wales and chocks ensuring that all contact surfaces at joints are welded all around. Install galvanized bolts and other support hardware. Install galvanic sacrificial anodes.

Exercise care in handling and driving fender piles to protect piles from damage. Where protective coatings are broken or damaged in any way, the areas should be surface cleaned of all scaled or chipped paint and new coating applied in accordance with approved standards. In a similar manner, all welded joints, drilled holes and other field connections should be carefully covered with protective coatings. See section 4.5.1. Figure 4-14 is an example of a design using steel piles.

**Application:** Replacement of steel fender piles, using the same pile design, should be used only when operational or economic constraints preclude using more advanced pile systems. See chapter 2 for guidance.

**Future Inspection Requirement:** Close monitoring of fender performance will be required to document rate and frequency of deterioration from corrosion or damage. Level I inspections should be adjusted as required if accelerated corrosion or damage is noted. Good documentation of maintenance/repair history is essential.

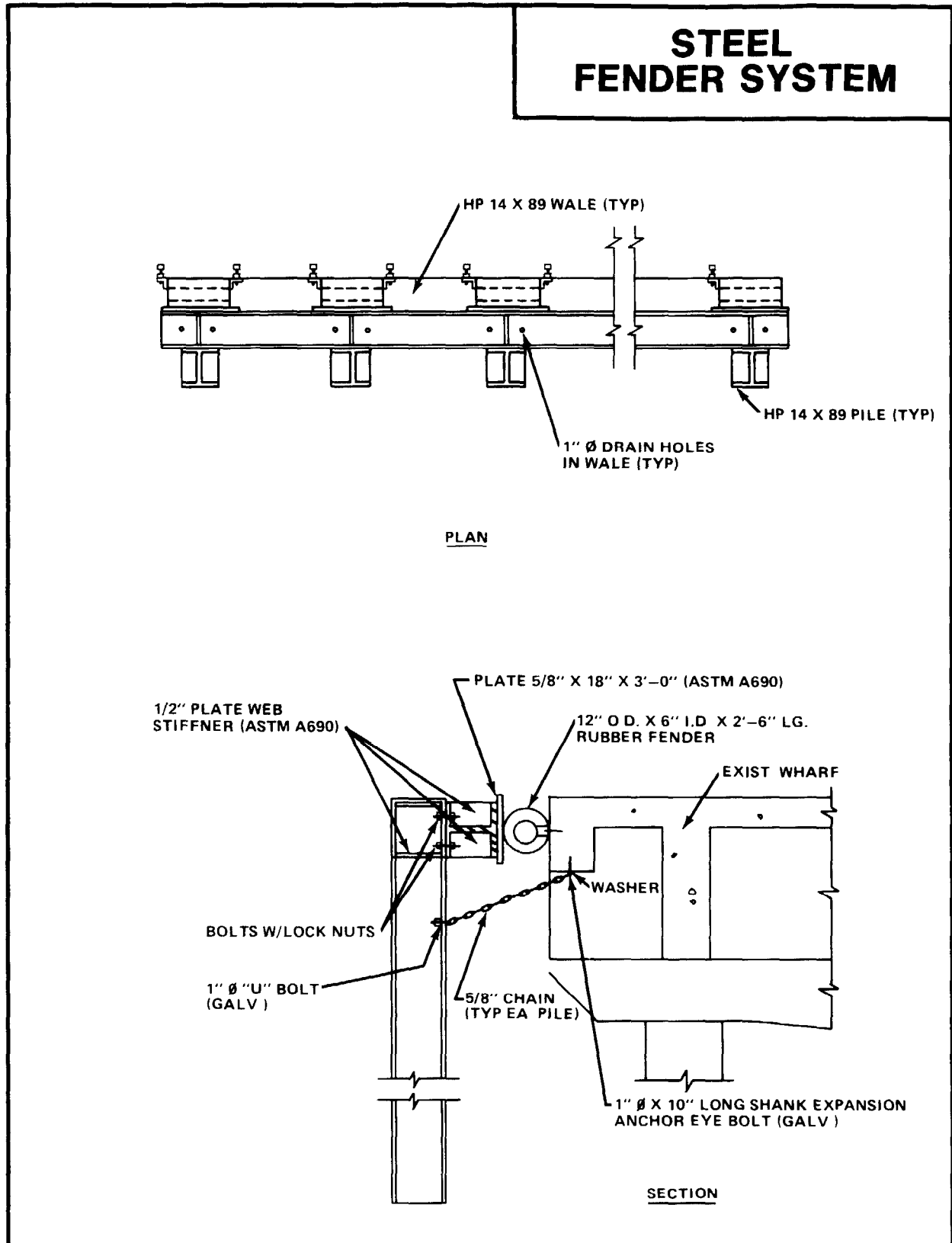


Figure 4-14. Example Design for Replacement of Steel Fender Piling.

## REPAIR STEEL FRAMED CAMEL

**Problem:** Steel framed camel has worn or damaged fender strips; corroded or damaged framing or welded joints; corroded or punctured flotation tanks causing listing or loss of freeboard; cracked or torn rubber fenders; and/or loose, damaged or missing hardware.

**Description of Repairs:** Remove the camel from the water, thoroughly clean the camel of all marine growth, scale and rust, and inspect for surface deterioration. Spot check suspected areas by sounding with a hammer and probing with a thin-pointed tool. Use calipers and scales to determine thickness of steel flanges, webs and plates. Check for corrosion or punctures on flotation tanks. Inspect wood and timber fendering, rubbing strips and decking. Probe with a thin-pointed tool for signs of fungus or rot damage. Inspect rubber fender for signs of cracking, tear or permanent set. Check cathodic protection system anodes, and all welds, bolts and other hardware. See figure 4-15.

Replace structural members and hardware as required. Ensure that all joint welds are performed in accordance with AWS D1.1 standards. Install galvanized bolts conforming to ASTM A 307.

Patch flotation tanks to restore buoyancy. If steel flotation tanks are used, consider replacing with reinforced fiberglass tanks.

Replace wood and timber rubbing strips, fenders, and decking as required. Ensure that all wood and timber products are treated with preservative in accordance with Federal Specification TT-W-571 and that all field cuts and holes are treated in accordance with AWWA Standard M4. See section 4.3.1.

Replace galvanic anodes if 80 percent consumed or if it is anticipated they will be consumed prior to next inspection.

Replace rubber fenders if worn, torn or punctured. If the fender shows signs of permanent set, replace immediately.

**Application:** Frequency of repair requirements, age, and repair costs will normally govern whether the steel framed camel is repaired, replaced by the same type system, or replaced by an alternative camel system.

**Future Inspection Requirements:** The inspection frequency should be based upon the age of the facility and historical records of the specific camel.

# REPAIR STEEL FRAMED CAMEL

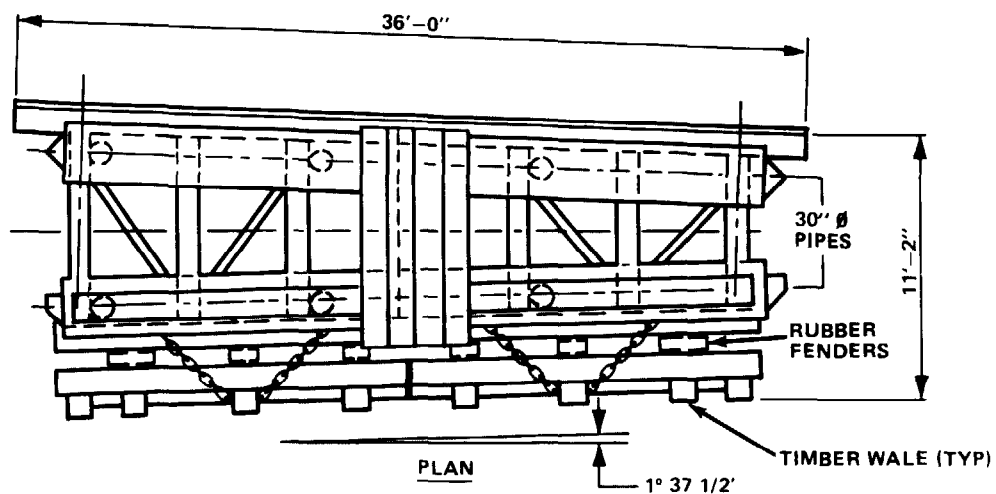
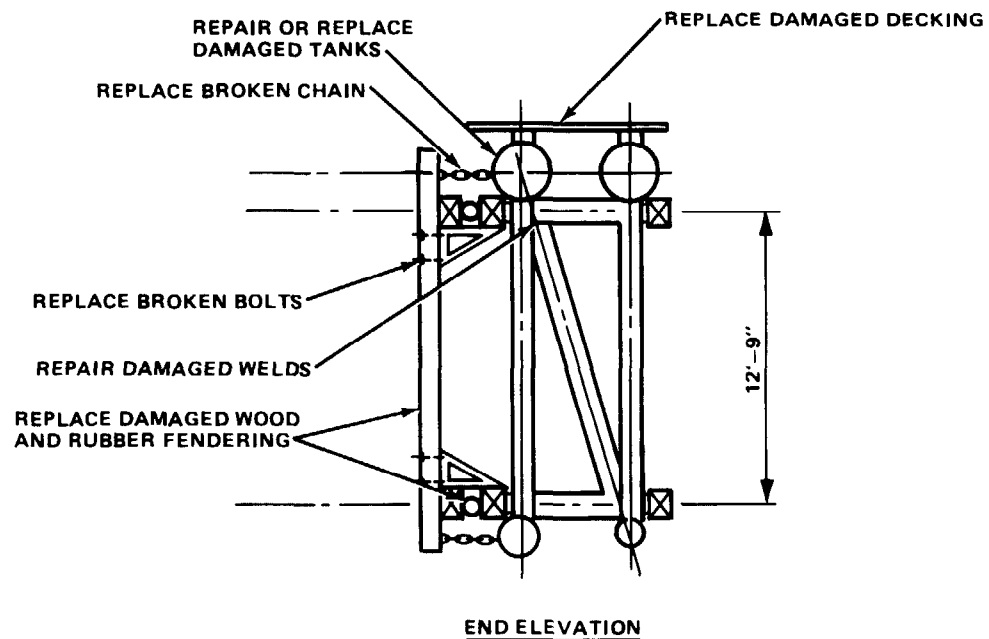


Figure 4-15. Typical Repairs to a Steel Framed Camel.

**4.6 SYNTHETIC MATERIALS.** Numerous synthetic materials are used on waterfront fender systems and camels. They are extremely versatile in application and serve as a structural material, coating material, or buoyancy material. In general, these materials do not corrode in the marine environment, but do deteriorate due to other reasons such as water absorption and swelling and degradation by ultraviolet light. The common synthetic materials include fiber-reinforced plastics (FRP), foams, rubbers and elastomers, plastic pile wraps, synthetic fibers, and adhesives. Typical applications include:

- Pile jackets and rubbing strips for piling to reduce erosion, abrasion and marine borer attack.
- Fiberglass flotation tanks for camels.
- Rubber fenders including compression and pneumatic fenders, and elastomer shells for foam-filled fenders.
- Foams for foam-filled fenders.

Deterioration of these synthetics increases with aging; plastics crack or separate, some types become brittle; foams crumble with age and lose resiliency; elastomers stretch and deteriorate from the effects of sun and exposure.

**4.6.1 Preventive Maintenance for Synthetic Materials.** In general, preventive maintenance measures for synthetic materials consist of selecting the right material to match the job requirements, and ensuring that the materials are not subjected to excessive stresses or caustic environmental conditions. Specific preventive maintenance measures that should be followed include:

- Inspecting and repairing fasteners of pile wraps and rubbing strips, ensuring use of alloy materials that will not rust in the marine environment.
- Adjusting tire nets on net type floating fenders to ensure even contact with the ship hull and pier surface.
- Ensuring that floating pneumatic or foam-filled fenders are not placed in the immediate vicinity of the ships' steam exhaust ports.
- Keeping floating fenders out of areas where chemicals are being used or are being transferred to the ship.
- Monitoring floating fenders to ensure that the fenders are in full contact with the fender piles or bearing panels.

Continuous inspection and recordkeeping are two critical elements that are keys to any preventive maintenance program for synthetic materials.

**a. Fiber-Reinforced Plastics.** Fiber-reinforced plastics are a composite of resin and fibrous material. The common resins are polyester and epoxy.

Polyester resins are general purpose resins that cost less than epoxy. Epoxy resins have superior strength properties, greater resistance to chemical and water degradation, and lower shrinkage during curing. Materials used as reinforcement for FRP include continuous strands, woven cloth, chopped fibers, and in some cases glass flakes.

**b. Foams.** Foams are utilized at the waterfront as a filler material for buoyancy and in foam-filled fenders to absorb the energy of berthing ships. Foams are resistant to deterioration in the marine environment provided they are encased in some impermeable, marine resistant layer.

The common foams are polyurethane, polystyrene, and polyethylene. Polyurethane foams can be foamed in place and are useful in public works. The disadvantages of polyurethane foam are its instability when exposed to direct sunlight and its flammability.

Polystyrene foams are relatively inexpensive compared to polyurethane. They can be purchased in large quantities and cut in shape. Polystyrene foams are used in decks for buoyancy of small boat moorings in marinas.

Polyethylene foams are used in foam-filled fenders. The foam, encased in an elastomer cover, absorbs the energy of impact of berthing ships.

**c. Rubber and Elastomers.** Numerous natural and synthetic rubbers and elastomers are used at the waterfront in fender system components and other specialized applications. These materials are resistant to the marine environment provided the appropriate rubber or elastomer is used. The more common material is a urethane elastomer as used for the shell of foam-filled fenders.

**d. Other Synthetic Materials.** Synthetic materials are also used at the waterfront for pile wraps and adhesives. Pile wraps are made of flexible polyvinyl-chloride (PVC) films and prevent growth of wood boring organisms.

Adhesives, coatings and putties made from epoxy have been developed for bonding to damp and underwater surfaces. They are used to bond structures or components, connections, joints and other metal configurations susceptible to corrosion, to fill voids, and to protect surfaces. They can also be used to patch holes above and underwater.

#### **4.6.2 Repair to Synthetic Material Components.**

**4.6.2.1 Pile Jackets and Rubbing Strips.** Repair requirements for pile jackets and rubbing strips will normally be generated by field exposure of the material and mechanical damage caused by external loads. In either case, repair will be by replacement. Each repair should be carefully documented and historical repair data should be evaluated for economic efficiency.

**4.6.2.2 Rubber Fenders.** Repair requirements for rubber fenders will normally result from mechanical damage leaving the fender worn, torn, or permanently set. Repair will be by replacement. Again each repair should be carefully documented.

**4.6.2.3 Foam-Filled Fenders.** Repair requirements for foam-filled fenders are directed at patching torn or worn shells. Repair to correct permanent set or deterioration of foam will normally be by replacement.

**4.6.2.4 Planning the Repairs.** Accomplishment of repairs to synthetic materials and components will be controlled by the position of the components (or material) within the waterfront structure. Components such as resilient rubber fenders and rubbing strips on piles will normally be repaired by replacement and are within the capability of shop forces. Repairs of coatings or jackets on piling will frequently involve skilled personnel and specialized equipment, necessitating repairs to be accomplished by contract. Repairs to foam-filled fenders may be accomplished either by shops forces or the manufacturer depending upon the extent of damage or deterioration.

Special instructions and equipment requirements for repairing foam-filled fenders are specified by the manufacturer. Repair kits for reinforced and unreinforced fender shells are made up of the following:

a. Unreinforced Fender Shell:

- Two-part elastomer and curative compounds
- Two-part primer
- Closed-cell polyethylene foam blocks
- Material data sheets

b. Reinforced Fender Shell: All items in section a. above plus:

- Nylon webbing (lacing)
- Nylon netting for repair of reinforcement
- Elastomer thickener

Other materials needed for the kit such as paper cups, razor blades, stirring sticks, masking tape, sand paper, paint brushes, and putty are items that can be readily acquired.

**4.6.2.5 Repair Procedures.**

**a. Rubber Fenders and Rubbing Strips.** Repair of rubber fenders and rubbing strips on piles will be by replacement and will be accomplished in accordance with standard shop industrial practices. Repair of coating or jacketing materials on piling will conform to the repair procedures outlined in reference 15.

**b. Net-Type Foam-Filled Fenders.** Field repairs to net type, foam-filled fenders may include repairs to chains and shackles, replacement of damaged or missing tires, or minor patching of skin damage. Major shell damage caused by over compression or wear should be repaired at the factory.

**c. Netless Foam-Filled Fenders.** Field repairs to netless, reinforced and unreinforced shell foam-filled fenders are outlined in synthetic material repair procedures that follow. Severe shell, foam and end fitting damage, caused by over compression, should be repaired at the factory.

## REINFORCED SHELL, FOAM-FILLED FENDER REPAIR

**Problem:** Minor shell abrasion, shell or foam burns, punctures, cuts or tears have occurred necessitating field repairs to prevent further damage.

**Description of Repairs:** Field repairs can be accomplished using a repair kit purchased from the manufacturer, or by developing an in-house repair capability and material inventory.

**Preparing Elastomer Components:** Heat the closed cans of elastomer polymer and curative components by either wrapping can several times with heat tape, or place in a pan of lukewarm water (120°F) for approximately 1 hour, or until completely melted.

### CAUTION

Do not boil the water. Fill the pan to a water level several inches below the top of can.

Mix curative thoroughly by slowly rolling the can across a table or ground for several minutes. Do not shake the can. Mix the required amount of components in a can and gently stir for 2-3 minutes. Avoid violent stirring that may cause air bubbles.

### NOTE

Usable pot life of the mixed components is approximately 10-15 minutes. Mix only as much as can be used in that time.

Place the entire content of the mixed components into the paper cups and mix thoroughly.

### Tears and Cracks:

- (1) Position the damaged fender so that the area to be repaired is easily accessible.
- (2) Buff from 6-8 inches around the perimeter of the crack and within the crack itself, with sidegrinder or sandpaper.
- (3) Drill a 1-inch diameter hole at each end of the crack. This should relieve the stress concentration and prevent further propagation.
- (4) Drill 1/2-inch diameter holes along both sides and parallel to the crack. Holes should be drilled 2-1/2 inches away from the crack and be 2-1/2 inches between centers. See figure 4-16.

## REINFORCED SHELL, FOAM-FILLED FENDER REPAIR (Continued)

- (5) Thread the nylon webbing through a 1/2 inch diameter hole at one end of the crack. Tie a knot large enough not to slip through the hole. The knot should be on the underside of the shell.
- (6) Start lacing webbing through the holes. Try not to twist the webbing; webbing should lay flat. Brazing or welding rod is a good tool for threading the webbing through the holes.
- (7) Lace webbing through all holes, tie a large loop in the running end and hook it to a come-along or chain jack. Pull the webbing tight using the come-along or chain jack.
- (8) Work out all slack in the webbing using a pry bar. Repeat operation until all the slack is drawn out and the crack is closed as much as possible.

### CAUTION

Webbing is rated at about 2500 pounds. Try not to pull the webbing beyond that limit.

- (9) Clean the area with any available solvent, while the come-along is still attached. Mask-off the buffed and cleaned area.
- (10) Mix primer in accordance with the directions and apply to the damaged area. Apply the primer inside as well as around the tear or crack. Allow the primer to dry for 30 minutes, or until tacky.
- (11) Cut out several patches of netting slightly smaller than the masked off area and set aside (omit where reinforcing is not required).
- (12) Spread elastomer mixture over the entire repair area.
- (13) Work a piece of pre-cut netting into the fresh mixture.
- (14) Apply a second coat of elastomer mixture and a second layer of netting while the previous coat is still tacky.
- (15) Allow the second coat to cure for 30 minutes and release the come along and trim off the end of the nylon webbing.

### NOTE

The webbing may slip back a little, but the elastomer mixture will keep the slippage from being excessive.

## REPAIR FOAM-FILLED FENDER

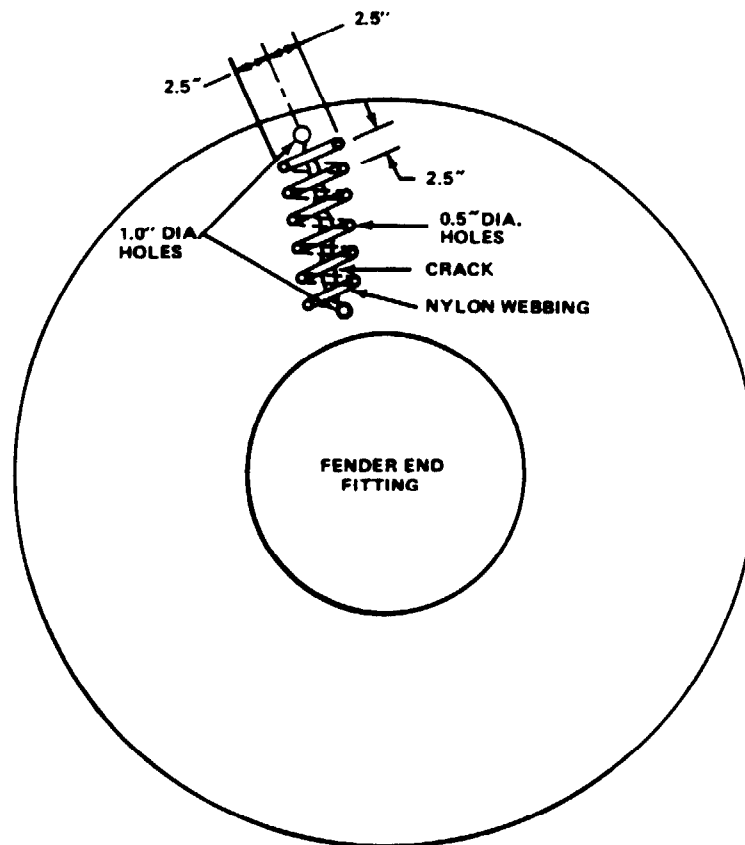


Figure 4-16. Repair of Tear in Reinforced Foam-Filled Fender Shell.

**REINFORCED SHELL, FOAM-FILLED FENDER REPAIR (Continued)**

- (16) Continue applying the mixture until the desired thickness is obtained.
- (17) Apply a final coat of the mixture to smooth out the final surface.

**Burns and Skin Removal:**

- (1) Position the damaged fender so that the area to be repaired is easily accessible.
- (2) Cut the damaged area into a smooth circular contoured shape. See figure 4-17.
- (3) Drill 1/2-inch diameter holes, 2-1/2 inches away from the edge of the undamaged skin and 2-1/2 inches between centers around the perimeter (figure 4-17).
- (4) Cut a patch of polyurethane similar in shape to the damaged area. Cut the patch so that it overlaps onto the undamaged shell by approximately 1-inch all around.
- (5) Lay patch over the damaged area and mark holes on the patch so that they match up with and are parallel to the holes on the undamaged shell. Marks should be placed 2-1/2 inches away from the edge of the patch.
- (6) Drill 1/2-inch diameter holes in the patch where marked.
- (7) Sand 6-8 inches around the perimeter of the undamaged shell.
- (8) Lace the nylon webbing.
- (9) Mix and apply primer.
- (10) Mix the elastomer components.
- (11) Spread the elastomer mixture over the entire work area.
- (12) Continue applying the mixture until the desired thickness is obtained.
- (13) Apply a final coat of the mixture to smooth out the final surface.

**Punctures and Gouges:**

- (1) Position the damaged fender so that the area to be repaired is easily accessible.

## REINFORCED SHELL, FOAM-FILLED FENDER REPAIR (Continued)

(2) Sand and clean around the perimeter and inside the puncture or hole. Use a solvent to clean the area.

(3) Mix and apply primer, and mix elastomer mixture.

### Foam Repair (If Applicable):

(1) Position the fender so that the area to be repaired is easily accessible.

(2) Cut away the damaged foam forming a rectangular cavity. Use a knife or razor blade to cut out damaged foam.

(3) Cut a block of foam approximately the same size as the rectangular cavity.

(4) Clean the inside of the cavity of foam and elastomer debris.

(5) Mix the elastomer mixture.

(6) Glue the foam block into the cavity using the elastomer mixture.

(7) Repair the shell of the fender by the appropriate method previously described.

**Application:** The shelf life of the unmixed two part elastomer compound is limited to 6-8 months. Therefore, it is advantageous to purchase the elastomer when the need arises.

In the field, fender repair will involve working with chemicals, so general safety precautions should be observed as follows:

- Avoid elastomer contact with skin and eyes.
- Wear gloves when working with materials.
- Store at temperature of 65° to 90°F.
- Treat spills with water, alcohol, or a mixture of saw dust and dilute ammonia.

**Future Inspection Requirements:** Increased inspection may be required to ensure that the seam or patch does not rupture.

## REPAIR FOAM-FILLED FENDERS

DAMAGED SHELL TRIMMED  
WITH HOLES DRILLED FOR  
NYLON LACING

ELASTOMER PATCH LACED  
ON FENDER SHELL

FINISHED REPAIR COATED  
WITH LIQUID ELASTOMER

Figure 4-17. Repair of Reinforced Foam-Filled Fender Shell.

## UNREINFORCED SHELL, FOAM-FILLED FENDER REPAIR

**Problem:** Minor shell abrasion, shell or foam burns, punctures, cuts or tears have occurred necessitating field repairs to prevent further damage.

**Description of Repairs:** Field repairs can be accomplished using a repair kit purchased from the manufacturer, or by developing an in-house repair capability and material inventory.

**Preparing Elastomer Components:** Heat the closed cans of elastomer polymer and curative components by either wrapping can several times with heat tape, or place in a pan of lukewarm water (120°F) for approximately one hour, or until completely melted.

### CAUTION

Do not boil the water. Fill the pan to a water level several inches below the top of can.

Mix curative thoroughly by slowly rolling the can across a table or ground for several minutes. Do not shake the can. Mix the required amount of components in a can and gently stir for 2-3 minutes. Avoid violent stirring that may cause air bubbles.

### NOTE

Usable pot life of the mixed components is approximately 10-15 minutes. Mix only as much as can be used in that time.

Place the entire content of the mixed components into the paper cups and mix thoroughly.

### Tears and Cracks:

- (1) Position the damaged fender so that the area to be repaired is easily accessible.
- (2) Using a sidegrinder, grind the edges and inside of the damaged area. Smooth all jagged edges and round off the ends of the tear to relieve stress concentration. See figure 4-18.
- (3) Clean off the damaged area.
- (4) Force uplift of skin back to its normal position with blocks of wood. Place wood across the uplift and hold down with metal strap (figure 4-19).
- (5) Construct a 1-inch high berm with commercial putty around the perimeter of the damaged area (figure 4-19).
- (6) Mix and apply the primer.

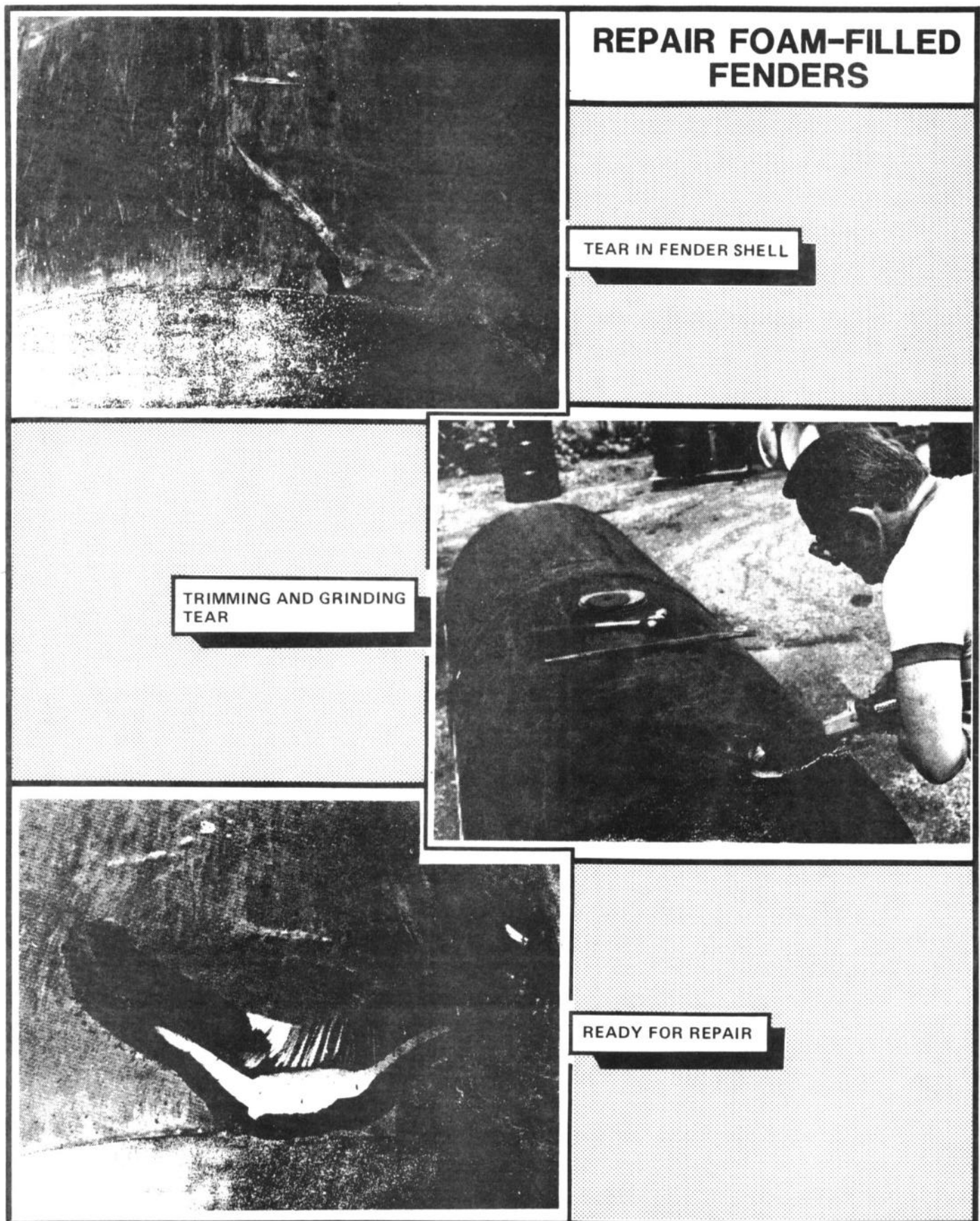


Figure 4-18. Preparing Tear in Unreinforced Foam-Filled Fender Shell for Repair.

## UNREINFORCED SHELL, FOAM-FILLED FENDER REPAIR (Continued)

- (7) Mix the elastomer compounds.
- (8) Pour mixture into the damaged area until it reaches the top of the berm (figure 4-19).
- (9) Let the elastomer cure.
- (10) Cut away the excess elastomer until flush with the original fender shell.

### Foam Repair (If Applicable):

- (1) Position the damaged fender so that the area to be repaired is easily accessible.
- (2) Cut away the damaged foam forming a rectangular cavity. Use a knife or razor blade to cut out damaged foam.
- (3) Cut a block of foam approximately the same size as the rectangular cavity.
- (4) Clean the inside of the cavity of foam and elastomer debris.
- (5) Mix the elastomer mixture.
- (6) Glue the foam block into the cavity using the elastomer mixture.
- (7) Repair the shell of the fender by the appropriate method previously described.

**Application:** The shelf life of the unmixed two part elastomer compound is limited to 6-8 months. Therefore, it is advantageous to purchase the elastomer when the need arises.

In the field, fender repair will involve working with chemicals, so general safety precautions should be observed as follows:

- Avoid elastomer contact with skin and eyes.
- Wear gloves when working with materials.
- Store at temperature of 65° to 90°F.
- Treat spills with water, alcohol, or a mixture of saw dust and dilute ammonia.

**Future Inspection Requirements:** Increased inspection may be required to ensure that the repair does not rupture.

## REPAIR FOAM-FILLED FENDERS

CURING THE PATCH

BLOCKS AND STRAPS HOLDING  
CUT SHELL IN PLACE. PUTTY  
BERM AROUND REPAIR AREA  
FILLED WITH LIQUID ELASTOMER

TRIMMING CURED  
ELASTOMER

FINISHED REPAIR COATED  
WITH LIQUID ELASTOMER

Figure 4-19. Repair of Unreinforced  
Foam-Filled Fender Shell.

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15. NAVFAC MO-310, Military Entomology Operational Handbook, Naval Facilities Engineering Command, Alexandria, VA, December 1971.
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17. **Design Manual NAVFAC DM-2.03, Structural Engineering - Steel Structures, Naval Facilities Engineering Command, Alexandria, VA, May 1980.**
18. **Naval Ships' Technical Manual, NAVSEA S9086-VD-STM-000.**
19. **Steel Structures Painting Manual.**
20. **Design Manual NAVFAC DM-4.10, Cathodic Protection Systems - Design.**

## APPENDIX A

### SPECIFICATIONS AND STANDARDS

Number	Document Title
<b>WOOD AND TIMBER</b>	
FED SPEC TT-W-571	Wood Preservation: Treating Practice
NFGS-02361	Round Timber Piles
ALSC	Lumber Standards
ASTM D 25	Round Timber Piles
AWPA C1, C3	Preservative Treatment, Pressure Process
AWPA M4	Standard for the Care of Pressure-Treated Wood Products
AWPB MP-1/MP-2/MP-4	Water-Borne Preservatives and Creosote Treatment for Marine Pilings
SSPC SP-1	Solvent Cleaning
<b>CONCRETE</b>	
FED SPEC TT-P-19	Paint, Latex (Acrylic Emulsion, Exterior Wood and Masonry)
FED SPEC TT-P-95	Paint, Rubber: For Swimming Pools and Other Concrete and Masonry Surfaces
FED SPEC TT-S-230	Sealing Compound: Elastomeric Type, Single Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures)
FED SPEC TT-C-555	Coating, Textured (For Interior and Exterior Masonry Surfaces)
MIL SPEC MIL-P-24441	Paint, Epoxy-Polyamide, Exterior Top coat, Dark Gray, Formula 155-RO = 6 Type 1
MIL SPEC MIL-C-83286	Coating, Urethane, Aliphatic Isocyanate, for Aerospace Applications
NFGS-02363	Cast-in-Place Concrete Piling, Steel Casing

**APPENDIX A (Continued)**

**SPECIFICATIONS AND STANDARDS**

<b>Number</b>	<b>Document Title</b>
	<b>CONCRETE (Continued)</b>
NFGS-(02XXX)	Prestressed Concrete Fender Piling (Draft)
NFGS-03300	Cast-in-Place Concrete
ACI 211	Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 212	Admixtures for Concrete
ACI 318 Series	Building Code Requirements for Reinforced Concrete
ACI 515	Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems
ACI 503R.1/2/3/4	Use of Epoxy Compounds with Concrete
ASTM A 82	Cold-Drawn Steel Wire for Concrete Reinforcement
ASTM A 416	Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete
ASTM A 615	Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM A 616	Rail Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 617	Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 775	Epoxy-Coated Reinforcing Steel Bars
ASTM C 33	Concrete Aggregates Specification
ASTM C 150	Portland Cement Specification
ASTM C 260	Air-Entraining Admixtures for Concrete
ASTM C 494	Chemical Admixtures for Concrete
ASTM C 881	Epoxy-Resin-Base Bonding Systems for Concrete

## APPENDIX A (Continued)

## SPECIFICATIONS AND STANDARDS

Number	Document Title
<b>STEEL</b>	
FED SPEC TT-P-645	Primer, Paint, Zinc Chromate, Alkyd Type
FED SPEC VV-P-236	Petrolatum, Technical
FED SPEC TT-E-490	Enamel, Silicone Alkyd Copolymer, Semigloss (For Exterior and Interior) Non-Residential
MIL SPEC MIL-C-18480	Coating Compound, Bituminous, Solvent, Coal-Tar Base
ASTM A 36	Structural Steel Specification
ASTM A 242	High-Strength Low-Alloy Structural Steel
ASTM A 307	Carbon Steel Externally Threaded Standard Fasteners
ASTM A 325	High Strength Bolts for Structural Steel Joints
ASTM A 572	High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality
ASTM A 588	High-Strength Low-Alloy Structural Steel 50 KSI minimum yield Point to 4 in. thick
ASTM A 690	High-Strength Low-Alloy Steel H-Piles and Sheet Piling for use in Marine Environments
AWS D1.1	Structural Welding Code, Steel
SSPC SP-5/SP-6/SP-10	Commercial Blast Cleaning
SSPC Paint No. 16	Coal-Tar Epoxy-Polyamide, Black, (or dark Red) Paint

**SYNTHETICS**

MIL SPEC MIL-F-29248	Fenders, Marine, Foam-Filled, Netless
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ACI - American Concrete Institute  
 ALSC - American Lumber Standards Committee  
 ASTM - American Society for Testing and Materials  
 AWS - American Welding Society  
 AWPB - American Wood Preservers Association  
 AWPB - American Wood Preservers Bureau  
 NFGS - NAVFAC Guide Specification  
 SSPC - Steel Structures Painting Council

## GLOSSARY

Anode	The consumable component (electrode) of cathodic protection systems and corrosion cells.
Apron	That portion of a wharf or pier carried on piles beyond solid fill.
As-built drawings	Drawings that show what was actually constructed with all deviations from the original design and changes made during construction.
Bent	Framework crosswise to the length of a structure (e.g., trestle, bridge, or pier) which it supports; usually designed to support stringers.
Berth	The water area at the edge of a wharf or pier reserved for a vessel.
Bulkhead	A retaining wall to prevent sliding of earth or fill into water.
Bullrail	A guard, usually wooden, located along the outer edge of a wharf or pier to prevent accidental loss of equipment into the water.
Caisson	(1) A watertight support foundation (cofferdam) formed by pouring concrete, driving sheet lock piling, or forming other material into a hollow box or cylinder; allows maintenance and repair work to be done below water level. (2) a controlled submergence floating hull used as a watertight entrance closure for a graving dock.
Camel	A floating device acting as a fender and used to separate a moored vessel from a pier, wharf, quay, or other vessel.
Cap	(1) A horizontal timber secured to the top of a row of piles. (2) A fitted or threaded piece to protect the top of a pile from damage while being driven.
Cathodic protection	An electrical method of preventing metal corrosion in a conducting medium by placing a charge on the item through a transformer or a sacrificial anode.
Chock	(1) A wedge or block, commonly wooden, fitted between piling or other structures to steady them. (2) A metal casting with two horn-shaped arms curving inward between which mooring lines may pass; used for passage, guiding, or steadying of mooring or towing lines.

## GLOSSARY (Continued)

<b>Cofferdam</b>	A temporary watertight enclosure from which water is pumped to expose normally immersed areas.
<b>Curb</b>	See bullrail.
<b>Deadman</b>	A block or other heavy item, usually of concrete, buried in the ground to which is attached a steel rod or cable for anchoring objects.
<b>Deck</b>	The working surface of a wharf, pier, or vessel.
<b>Dock</b>	The water area adjacent to a wharf or pier to which a ship can be secured.
<b>Dolphin</b>	A structure usually consisting of a cluster of timber piles. It is placed at the outward end of piers and wharves, or along shore, to guide vessels into their moorings, to fend vessels away from structures, shoals, or the shore, or to support navigation aids.
<b>Elastomer</b>	An elastic rubberlike substance (such as a synthetic rubber or a plastic having some of the physical properties of natural rubber).
<b>Electrolyte</b>	A nonmetallic medium capable of conducting electricity by the movement of ions rather than electrons.
<b>Fender</b>	A device, usually of wood, rubber, or rope to prevent damage to a vessel or shore facility by impact or abrasion.
<b>Fish plate</b>	A steel plate that laps a joint or an area of a piling reduced by corrosion. It is secured to the sides so as to connect the members end to end or to strengthen them.
<b>Float</b>	A floating platform used for disembarking from a boat or working around waterfront structures.
<b>Fouling</b>	An accumulation of deposits, especially marine biological growth.
<b>Gad</b>	A pointed iron or steel bar for loosening rock.
<b>Gravity wall</b>	A massive structure that obtains stability through its own weight.
<b>Holiday</b>	A small hole in a coated surface arising from imperfect application.

## GLOSSARY (Continued)

Incise	To make cuts into wood parallel to the grain to permit the take up of greater quantities of preservative.
Leaching	The process of extracting the soluble components from a material by percolation.
Marine borer	Destructive organism in seawaters that attacks untreated or poorly treated wood; especially active in warm waters.
Mill scale	Oxide layer formed on iron and steel when heated for rolling, forging, or other processing.
Pier	An open or closed-type structure usually extending perpendicularly from the shore into sheltered navigable water, designed for berthing, loading or unloading cargo, repair, fueling, and general servicing of vessels. It normally provides berthing space on both sides for its entire length.
Piezometer	An instrument for measuring pressure or compressibility.
Pile (piling)	A long, slender timber, steel, or reinforced concrete structural element driven, jetted, or otherwise embedded into the ground or support a vertical load, to resist a lateral force, or to resist water or earth pressure.
Preservative	A material with the property of retarding deterioration.
Quay	See wharf.
Quaywall	A heavy structure fronting on navigable water, and parallel to the shore, behind which earth fill is placed. Its function is to act as a bulkhead as well as to provide for berthing of vessels or other service.
Radiography	The process of making a picture upon a sensitive surface by a form of radiation other than light. It is used for detecting flaws in welds or other metal structures.
Seasoning check or crack	A lengthwise separation of a wooden timber that extends across the rings of annual growth and commonly results from stresses set up in the wood during seasoning.
Seawall	A massive gravity-type structure built along, and generally parallel to, the shoreline; designed to protect the shore against erosion resulting from wave action.

## GLOSSARY (Continued)

Shoreline	The boundary area where water meets land.
Stanchion	An upright bar, post, or support usually on a ship.
Stringer	A horizontal framing member used to support a floor or deck.
Tremie	A steel tube 12 inches or greater in diameter used for depositing concrete underwater, having at its upper end a hopper for filling.
Turning basin	An enlarged space at the end of a canal or narrow channel to permit vessels to turn around.
Ultrasonic testing	High frequency sound readings to determine voids in landfills and flaws in welds, etc.
Wale	A long, horizontal structural member of timber or steel used for bracing vertical members. Also known as "waler" or "ranger."
Weep hole	An opening in a retaining wall, canal lining foundation, or other structure to drain away accumulated water.
Wharf	An open-type marginal platform structure, usually parallel to the shoreline, that is used primarily for berthing of vessels. It is usually connected to the shore at more than one point but may also have continuous access along the shore. It ordinarily provides berthing along the outboard face.

## INDEX

	Page
<b>Camels</b>	
Damage Areas, steel.....	3-19
Damage Areas, timber.....	3-17
Inspection of steel.....	3-18
Inspection of timber.....	3-16
Log.....	2-8, 2-10
Repair to steel.....	4-31
Repair to timber.....	4-7
Steel.....	2-8, 2-12
Submarine Separator.....	2-11
Timber.....	2-8
<b>Cathodic Protection.....</b>	<b>4-30</b>
<b>Coatings</b>	
Concrete.....	4-14
Steel.....	4-29
<b>Fender Systems</b>	
Fixed.....	2-1
Floating.....	2-8
<b>Floating Fender Systems.....</b>	<b>2-8</b>
Foam-filled.....	2-8
Pneumatic.....	2-8
<b>Foam-Filled Fenders.....</b>	<b>2-8</b>
Inspection of.....	3-14
Repair.....	4-44
<b>Inspection</b>	
Concrete Piling.....	3-10
Documentation.....	3-5
Foam-filled Fenders.....	3-14
Level I.....	3-1, 3-2
Level II.....	3-2, 3-4
Level III.....	3-2
Steel camels.....	3-18
Steel piling.....	3-12
Submarine camels.....	3-20
Timber camels.....	3-16
Timber piling.....	3-8
Tools.....	3-5
<b>Piles/Piling</b>	
Concrete, fabrication.....	4-18
Concrete, inspection.....	3-10

# INDEX

	PAGE
Concrete, repair.....	4-17
Concrete, replacing.....	4-26
Steel, cathodic protection.....	4-30
Steel, inspection.....	3-12
Steel, repair.....	4-31
Steel, replacement.....	4-38
Timber, inspection.....	3-8
Timber, repair.....	4-8
Timber, replacing.....	4-10
<b>Pressure Treatment.....</b>	<b>4-3</b>
<b>Preventive Maintenance</b>	
Concrete.....	4-14
Steel.....	4-29
Synthetic Materials.....	4-42
Timber.....	4-3
Wood.....	4-3
<b>Repair Procedures</b>	
Concrete fender systems.....	4-24
Foam-filled fenders.....	4-44
Rubber fenders.....	4-44
Steel camels.....	4-40
Steel fender piles.....	4-31
Timber camels.....	4-12
Timber piles.....	4-8
<b>Rub Strips.....</b>	<b>4-15</b>
<b>Synthetic Materials</b>	
Fiber-reinforced plastics.....	4-42
Foams.....	4-43
Repair procedures.....	4-44
Repair to.....	4-43
Rubber and elastomers.....	4-43