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640.01 General

This chapter provides guidance on the design of fixed dolphins. Fixed dolphins serve a number of functions: as protection of adjacent properties (e.g., marinas and breakwaters) or other WSF structures (e.g., wingwalls and overhead loading facilities), as approach and berthing aids, as means to remain stationary during loading and unloading operations, and as mooring points for overnight tie-up. Fixed dolphins serve both operating slips and tie-up slips.

The maximum depth of water for which fixed dolphins can be designed and constructed is approximately 45 ft. In water deeper than 45 ft, floating dolphins become a more feasible and economical alternative. Refer to [Chapter 650](#) for more information.

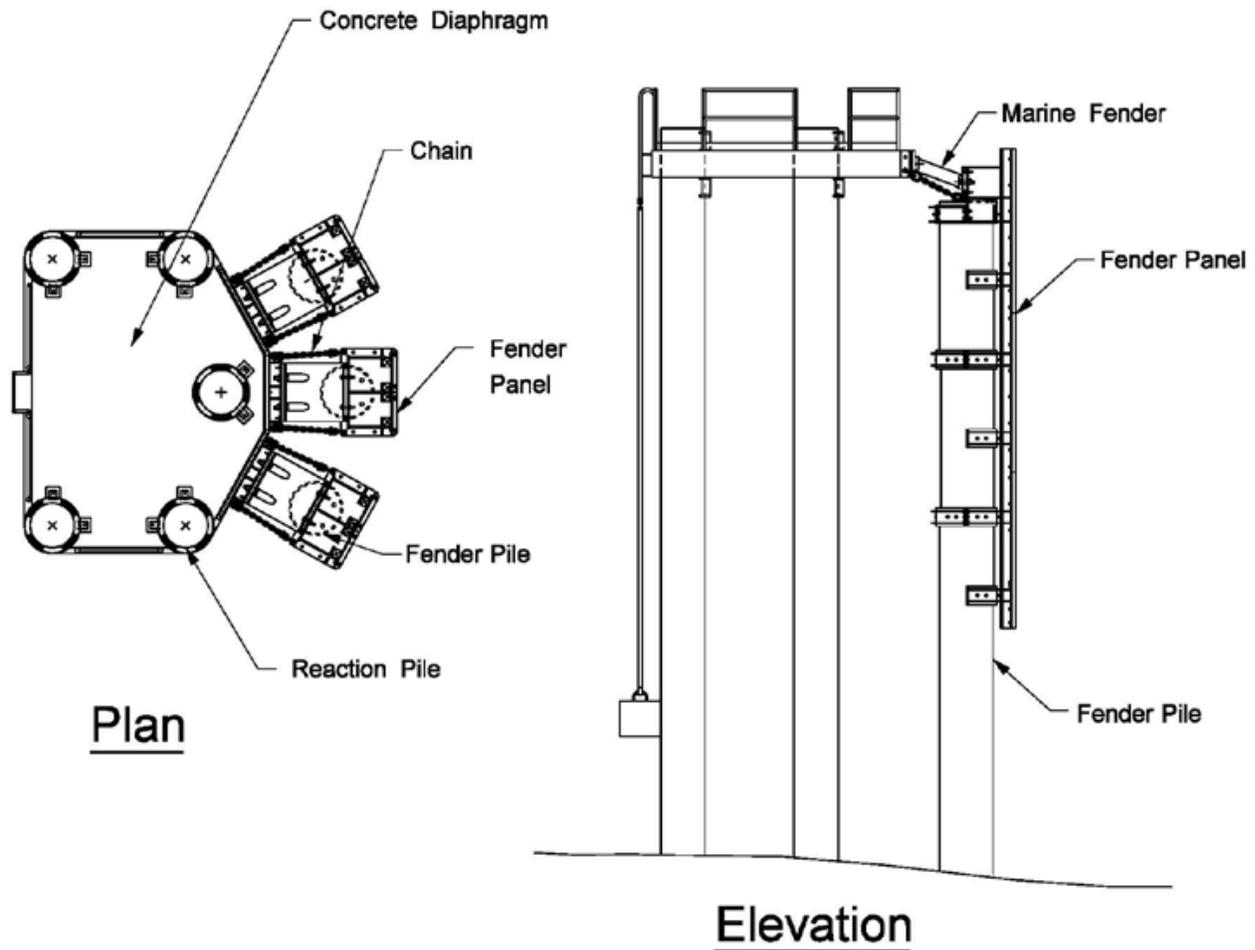
Typical fixed dolphins are illustrated in [Exhibit 640-1](#). The principal components of fixed dolphins are illustrated in [Exhibit 640-2](#).

For additional information, see the following chapters:



Typical Fixed Dolphins
Exhibit 640-1

Chapter	Subject
320	Environmental Considerations
330	Marine
650	Floating Dolphins



Typical Fixed Dolphin Components
Exhibit 640-2

640.02 References

Unless otherwise noted, any code, standard, or other publication referenced herein refers to the latest edition of said document.

(1) Federal/State Laws and Codes

Structural Welding Code – Steel (AWS D1.1: 2010)

Structural Welding Code – Reinforcing Steel (AWS D1.4:2005)

[WAC 296-24](#) *General Safety and Health Standards*

[WAC 296-56](#) *Safety standards – longshore, stevedore and waterfront related operations*

[WAC 296-876](#) *Ladders, portable and fixed*

(2) Design Guidance

[Bridge Design Manual LRFD](#) M 23-50

[Building Code Requirements for Structural Concrete](#) (ACI 318-08), American Concrete Institute

Design: Moorings, UFC 4-159-03, Department of Defense, Washington, DC 2005

Design: Piers and Wharves, UFC 4-152-01, Department of Defense, Washington, DC 2005

General Special Provisions

Geotechnical Design Manual M 46-03

Guidelines for the Design of Fender Systems: 2002, The World Association for Waterborne Transport Infrastructure (PIANC), 2002

Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-10), American Society of Civil Engineers

Region General Special Provisions, WSF

Specification for Structural Steel Buildings (ANSI/AISC 360-05), American Institute of Steel Construction

SSPC Painting Manual – Volume 2 Systems and Specifications (2011 Edition)

Standard Specifications for Road, Bridge, and Municipal Construction M 41-10

640.03 Design Considerations

(1) Location

Consult with WSF Operations staff to determine the location of fixed dolphins. [Chapter 330](#) provides design guidelines on WSF dolphin configurations.

(2) Environmental

Refer to [Chapter 320](#) for general environmental requirements and design guidance. Refer to the project NEPA/SEPA documentation for project-specific environmental impacts and mitigation.

(3) Marine

Refer to [Chapter 330](#) for general marine design criteria pertaining to fixed dolphins. Below are links to relevant sections by topic.

- Operations and Maintenance: [330.04\(4\)](#)
- Proprietary Items: [330.04\(6\)](#)
- Long Lead Time Items: [330.04\(7\)](#)
- Design Life: [330.04\(8\)](#)
- Corrosion Mitigation: [330.04\(9\)](#)
- Scour and Mudline Elevations: [330.04\(10\)](#)
- Material Specifications: [330.04\(12\)](#)
- Tidal Information: [330.06](#)
- Slips: [330.07](#)
- Berthing and Mooring Criteria: [330.08](#)

(4) **Geotechnical Requirements**

Design piles in accordance with the Geotechnical Recommendations provided by the WSDOT Geotechnical Branch. Do not include seismic effects including liquefaction in the design. The Geotechnical Recommendations will typically include:

- Axial capacity of piles
- Input data for L-Pile lateral analysis
- Group reduction factors due to pile spacing
- Constructability recommendations including type and capacity of pile driving equipment and use of cutting shoes.

640.04 Design Criteria

(1) **General**

Fixed dolphins are flexible pile-supported structures designed to absorb a vessel's kinetic energy through rotation and bending of the fender and reaction piles, compression of the marine fenders, and movement of the piles through the soil. The dolphin is sized in accordance with the design energy which is a function of the design vessel's mass, velocity, and approach angle, and other variables and constants. The dolphin may be single-sided or double-sided depending on the slip layout.

(2) **Design Vessel**

Refer to [Chapter 330](#) for design vessel information and [Appendix O](#) for vessel particulars. Consider WSF's future plans for vessel assignment to the subject terminal and slip. The design vessel is determined in consultation with WSF Operations staff.

(3) **Design Life**

Design lives for the following components of the fixed dolphins are based on deterioration due to corrosion and/or fatigue in accordance with the LCCM.

- Piles, fender panels, and diaphragms: 50 years
- Marine fenders: 30 years
- UHMW polyethylene rub panels: 20 years
- Chain and hardware: 20 years

(4) **Design Loads**

Design fixed dolphins for dead loads, live loads, berthing forces, and overnight mooring conditions. Wind, wave, current, and tide effects are considered insignificant and are not included in the analysis. Seismic forces also are not included in the analysis.

Design fixed dolphins with load definitions, factors, and combinations in accordance with the provisions of Section 2.4 of [Minimum Design Loads for Buildings and Other Structures](#) (ASCE/SEI 7-10), except as modified below. Design fixed dolphin reinforced concrete in accordance with the provisions of Section 2.3 of ASCE/SEI 7-10.

(a) Load Definitions

D = dead load of structural components and nonstructural attachments

L = live loads

CV = vessel collision force

(b) Dead Loads, D

Dead loads associated with the structure are permanent loads that do not change during the service life of the wingwalls. Dead loads include:

- Weight of the steel piling and structural steel
- Weight of the reinforced concrete diaphragm
- Weight of the fender system

Use the following material unit weights for calculation of loads:

Material	Unit weight (lb/ft ³)
Steel (all types)	490
Reinforced Concrete	155
Rubber	80
UHMW	60

Material Unit Weights (in air) for Structural Loading
Exhibit 640-3

(c) Live Load, L

Live loads associated with the normal operation of the fixed dolphins are loads that could change during the mode of operation considered and are controllable through operating procedures. Live loads consist of the Type I berthing events and maintenance crew loading of ladders and platforms. Personnel are never on the dolphins during berthing events.

(d) Vessel Collision Load, CV

Vessel collision load consists of the Type III berthing event.

Design Load	Combination
Type I Impact (Piling and all other Steel, Foundations, Deflection Analysis)	$S = D + L$
Type I Impact (Reinforced Concrete)	$U = 1.2 D + 1.6 L$ $U = 0.9 D + 1.6 L$
Type III Impact (Pushover Analysis)	$S = D + CV$

Load Combinations and Load Factors
Exhibit 640-4

(5) Design Velocities and Energies

Determine berthing velocities for bow impacts to dolphins from global positioning data furnished by WSF Operations staff in the form of approach velocity-versus-distance from apron data. Base drift impact velocities on past experience with this type of approach. Drift impact velocities typically apply only to outer and intermediate dolphins. Calculate berthing energies in accordance with the provisions of Section 5-2 of the *UFC: Design: Piers and Wharves* (UFC 4-152-01), unless noted otherwise in the project-specific criteria. Complete the table as shown in [Exhibit 640-5](#) for the dolphin(s) to be designed.

Dolphin	Impact	Angle (degrees)	Vessel Impact Velocity (knots)	Vessel Impact Velocity (feet per second)	Design Energy (kip-feet)
Outer	Bow	measured	calculated	calculated	calculated
	Drift	90	1.0	1.69	calculated
Intermediate	Bow	measured	calculated	calculated	calculated
	Drift	90	1.0	1.69	calculated
Inner	Bow	measured	calculated	calculated	calculated

Note: Bow impact angle is defined as the angle between the vessel centerline and the berthing velocity component normal to the dolphin fender panel face.

Type I Impact Berthing Velocities and Energies *Exhibit 640-5*

(6) Pile Allowable Stress

Design steel piles for an allowable stress in flexure of 0.90 times the yield stress under normal operating conditions (Type I Impact) steel piles.

640.05 Fixed Dolphin Alternatives

The standard fixed dolphin design utilizes pile fixity in the soil and a non-rigid diaphragm at the top of the reaction piles to achieve the required structural stability and flexibility (see [Exhibit 640-2](#)). At the majority of terminals there exists adequate soil depth to allow piles to be driven, either by vibratory or impact methods, to the embedment required for fixity. The loose connection between the concrete diaphragm and the pile tops allows the piles to act as cantilevers, thereby contributing to the energy absorption capacity of the dolphin as a whole.

At those terminals where inadequate soil exists (for example at Lopez Island), alternative designs have been developed in which fixity is achieved at the pile top through a rigid connection to the diaphragm and an unfixed (or pinned) condition is achieved at the pile tip-bedrock interface (see [Exhibit 640-6](#)). Flexibility is maintained and stability is achieved by anchoring the piles into the bedrock using permanent rock anchors.

In both cases, energy absorption is achieved through a combination of pile bending, diaphragm displacement and rotation, and marine fender compression.



Lopez Fixed Dolphin
Exhibit 640-6

640.06 Miscellaneous Design

(1) *Vessel Tie-up and Navigational Aids*

Consult with WSF Operations staff to determine the location of tie-up mooring lines. The outermost dolphin on each side of the slip is typically outfitted with a directional triangle that points toward the center of the slip and with a marine lantern that provides an aid to navigation at night (see [Exhibit 640-7](#)).



Fixed Dolphin Navigational Aids
Exhibit 640-7

(2) Ladders

Furnish each dolphin with a maintenance ladder sized to meet all applicable WAC and OSHA requirements and located away from the slip centerline (see [Exhibit 640-8](#)).



Fixed Dolphin Maintenance Ladder
Exhibit 640-8

(3) Bird Deterrence

At certain terminals nesting birds can create a maintenance nuisance resulting in health risks and environmental permitting issues. When directed by the Maintenance staff, include bird deterrent measures (bird wire and bird spikes) on the fender panels (see [Exhibit 640-8](#)).