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## 650.01 General

This chapter provides guidance on the design of floating dolphins. Floating dolphins serve a number of functions: as protection of adjacent properties (e.g., marinas and breakwaters), as approach and berthing aids, as a means to remain stationary during loading and unloading operations, and as mooring points for overnight tie-up.

Floating dolphins are used primarily at terminals with deep water (typically deeper than 45 feet) or where the presence of bedrock makes pile-supported fixed dolphins impractical. At such locations, the construction of fixed pile-supported structures will be much more expensive and difficult. Also, many vessel captains prefer floating dolphins over fixed dolphins since they are typically a much softer berthing element.

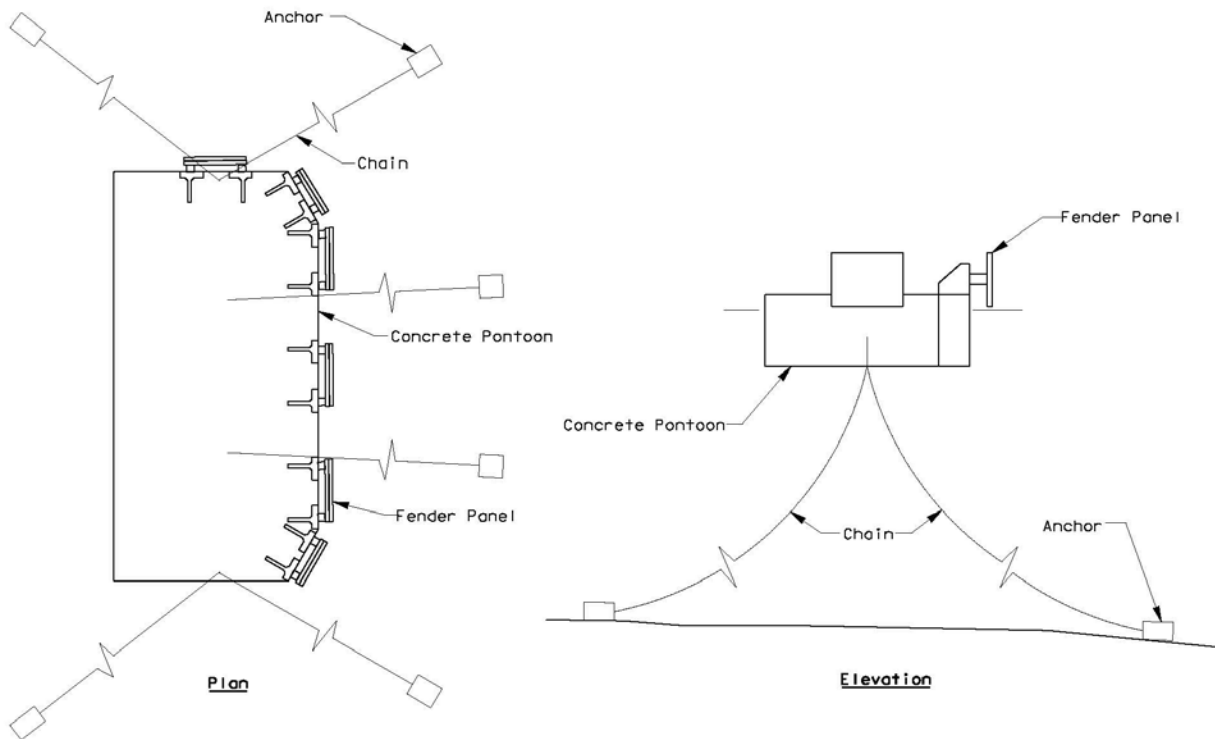
A typical floating dolphin is illustrated in [Exhibit 650-1](#). The principal components of floating dolphins are illustrated in [Exhibit 650-2](#).



**Typical Floating Dolphin**  
*Exhibit 650-1*

For additional information, see the following chapters:

Chapter	Subject
320	Environmental Considerations
330	Marine
640	Fixed Dolphins



**Typical Floating Dolphin Components**  
**Exhibit 650-2**

## 650.02 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

[46 Code of Federal Regulations \(CFR\) Part 170 Subpart E, Weather Criteria](#)

[46 CFR Part 174 Subpart C, Special Rules Pertaining to Mobile Offshore Drilling Units](#)

[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](#)

[Design: Piers and Wharves, Unified Facilities Criteria \(UFC\) 4-152-01, Department of Defense, Washington, DC 2005](#)

[Design: Moorings, UFC 4-159-03, 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

AASHTO *LRFD Bridge Design Specifications*, American Association of State Highway and Transportation Officials, Washington DC

Region General Special Provisions, WSF

*Specification for Aluminum Structure*, Aluminum Association

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

*Structural Welding Code – Steel* (AWS D1.1), American Welding Society

*Structural Welding Code – Reinforcing Steel* (AWS D1.4), American Welding Society

*Structural Welding Code – Aluminum* (AWS D1.2), American Welding Society

*Control of Cracking in Structural Concrete*, ACI 224R, American Concrete Institute

*Standard Plans for Road, Bridge, and Municipal Construction* M 21-01

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

*Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 5th ed. with Interim Revision*, AASHTO, Washington, DC 2009

*Velocity Pattern Generated by Propulsion of Four Ferries*, Pacific International Engineering Draft Technical Memorandum, 2001

## 650.03 Design Considerations

### (1) Location

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

Tune the translational response of the dolphin as much as practical to the current operational norm of 5 to 10 feet in the typical berthing contact. Accomplish this by adjusting the catenary shape of the anchor lines. Within limits, adjustment to the plan locations of the dolphins can be made if the vessel captains request a location adjustment at the time of installation, or after installation. The position of the dolphin can be adjusted by plus or minus 10 feet by changing the length of the anchor chains.

### (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 floating 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 anchors 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:

- Type of anchors to be used
- Resistance and safety factors to be used for the given anchors
- Capacity charts or values for the given anchors

**650.04 Design Criteria****(1) General**

Floating dolphins are moored concrete pontoons with standard dimensions as shown in [Exhibit 650-3](#) below. Two standard sizes are used depending on whether the dolphin is single-sided or double-sided. Design the float to consist of the number of individual cells tabulated below, each capable of being independently ballasted to attain level trim. Moor each dolphin with the number of chain mooring lines tabulated below and secure the chains to the sea bed with anchors. Locate one or more sinkers along the length of each mooring line as required to control the mooring line response and help meet energy design levels. Sinkers can also provide more vertical clearance between the vessel and the mooring lines. Typically for single-sided dolphins sinkers are provided only on the slip-side mooring lines.

Characteristic	Single-sided	Double-sided
Pontoon Length	80 feet	80 feet
Pontoon Width	40 feet	48 feet
Pontoon Depth	14 feet	14 feet
Number of Cells	21	24
Number of Mooring Lines	6	8

**Standard Floating Dolphin Characteristics**  
*Exhibit 650-3*

**(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 floating dolphins are based on deterioration due to corrosion and/or fatigue in accordance with the LCCM.

- Pontoon: 50 years
- Mooring chain and anchors: 25 years
- Marine fenders: 30 years
- UHMW polyethylene rub panels: 20 years
- Fender chain and hardware: 20 years

**(4) Design Loads**

Design floating dolphins for dead loads, live loads, berthing, overnight mooring, wind, wave, current, and tidal conditions. Berthing loads are due to the ferries laying into the dolphins as they enter the slip. Wind, wave, current, and tide are important in designing the mooring lines for the berthing loads as well as float motions. Float motions, resulting from wind, wave and current environmental loads, are important to berthing vessels because excessive movement may result in the dolphin impacting nearby structures, damage to the ferries, or overload of the mooring system.

**(a) Load Designations**

DC = dead load of structural components and nonstructural attachments

DW = dead load of wearing surfaces and utilities

LL = live load

EQ = seismic force

WA = static water loads and current pressure

BY = buoyant force

WS = wind force on structure

WV = wave force on structure

CV = vessel collision force

TU = uniform temperature

SH = shrinkage

EL = locked-in force effects

**(b) Permanent (Dead) Loads, DC and DW**

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

- Weight of the concrete pontoon
- Weight of permanent ballast
- Weight of the fender system
- External hydrostatic pressure and buoyancy in calm sea conditions assuming dolphin is submerged to the design waterline. Hydrostatic pressures shall be based on a water level 1 foot higher than the design waterline.
- Anchor chain force in calm sea conditions

Use the following material unit weights for calculation of loads:

Material	Unit weight (lb/ft <sup>3</sup> )
Reinforced Concrete	160
Steel (all types)	490
Aluminum	165
Rubber	80
UHMW	60
Ballast	120

**Material Unit Weights (in air) for Structural Loading**  
*Exhibit 650-4*

The unit weight of seawater is 64 pounds per cubic foot. Calculate the buoyant weight of other materials at their unit weight minus the unit weight of seawater.

Include marine growth as 5 pounds per square foot (submerged weight) uniformly distributed over submerged concrete faces.

**(c) Live Loads, LL**

Live loads associated with the normal operation of the dolphin are loads that could change during the mode of operation considered and are controllable through operating procedures. Live loads include:

- Type I berthing events from WSF ferry vessels
- A concentrated load of 2000 pounds acting anywhere on the top or keel slabs
- A uniform distributed live load of 40 pounds per square foot at any location or locations on the top or keel slabs
- Forces exerted on the dolphin from towing. Specify the maximum towing load (obtained by limiting tow cable load) and used for this load.

**(d) Seismic, EQ**

The floating dolphin is not designed for any seismic loads.

**(e) Water Load, WA and BY**

Water loads include the buoyant uplift force as well as horizontal fluid pressure. This includes the current generated by a maximum propeller wash velocity of 19 feet per second. This does not include loads due to waves.

When determining hydrostatic pressures, assume a water level 1.0 foot above design freeboard.

**(f) Wind and Wave Loads, WS and WV**

Includes both wind and wave loads on the structure. Design wind speed is site-specific.

**(g) Vessel Collision Load, CV**

Consider vessel collisions beyond the Type I berthing event.

**(h) Temperature and Shrinkage, TU and SH**

Use a load factor of 1.20 for temperature and shrinkage when deformations are being calculated. For all other effects use the load factor from [Exhibit 650-5](#).

**(i) Locked-in Force Effects, EL**

Accumulated locked-in force effects resulting from construction process, including the secondary forces from post-tensioning.

**(j) Load Factors and Combinations**

Load factors and combinations are based on Table 3.4.1-1 of AASHTO [LRFD Bridge Design Specifications](#).

**1. Strength I**

Basic load combination for normal use of facility without wind or wave when typical live load is considered.

**2. Strength III**

Load combination relating to facility exposed to a “design” storm.

**3. Strength V**

Load combination relating facility exposed to an “operational” storm.

**4. Extreme Event II**

Load combination relating to vessel collision forces beyond the Type I berthing event.

**5. Service I**

Load combination relating to the normal operational use of the facility.

Load Combination Limit State	DC DW EL	LL	WA BY	WS WV	TU SH	CV
Strength I	$\gamma_p$	1.75	1.00	—	0.50	—
Strength III	$\gamma_p$	—	1.00	1.40	0.50	—
Strength V	$\gamma_p$	1.35	1.00	0.40	0.50	—
Extreme Event II	$\gamma_p$	0.50	1.00	—	—	1.00
Service I	1.00	1.00	1.00	0.30	1.00	—

**Load Combinations and Load Factors**  
*Exhibit 650-5*

Type of Load	Load Factor, $\gamma_p$	
	Maximum	Minimum
DC: Components and Attachments	1.25	0.90
DW: Wearing surface and Utilities	1.50	0.65
EL: Locked-in Force Effects	1.00	1.00

**Load Factors for Permanent Loads,  $\gamma_p$**   
*Exhibit 650-6*

**(k) Damage States**

Evaluate the dolphin and moorage system to prevent failure due to damage loads. Damage loads include evaluation of the following:

- Type III berthing event. Design the dolphin and moorage system to provide continuous energy dissipation response to ferry berthing events with energy level in excess of the quantified Type I berthing event. Accomplish this by providing a mechanism for sliding anchorage. There is no quantified design energy level for a Type III berthing event.
- Flooding damage. Design the concrete pontoon to remain afloat (and stable as defined by [Section 650.05](#)) with complete flooding of one cell (full height), such as may occur in the event of a hull breach.



### (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. 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 shown in [Exhibit 650-7](#).

Dolphin	Impact	Angle (degrees)	Vessel Impact Velocity (knots)	Vessel Impact Velocity (feet per second)	Energy (kip-feet)
Floating	Bow	measured	calculated	calculated	calculated
	Drift	90	1.0	1.69	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 650-7*

### 650.05 Stability

Check the following four conditions for dolphin stability: stability of the dolphin anchored in its final location (anchored stability) and stability of a free-floating dolphin before being anchored (free-floating stability) with intact and damaged cases for both.

#### (1) Anchored Stability

- An anchored intact dolphin is considered stable if the metacentric height (GM) is greater than 2.0 and the deck does not go awash during a Type I berthing event.
- An anchored damaged dolphin is considered stable if the metacentric height (GM) is greater than 1.0 and the deck does not go awash with one cell flooded.

#### (2) Free-floating Stability

- A free-floating intact dolphin (during launching or towing) is considered stable if the area under the righting arm curve up to the downflooding angle is greater than or equal to 10.0 foot-degrees as per [46 CFR 174.015](#). The downflooding angle is defined as when the deck goes awash.
- A free-floating damaged dolphin (during launching or towing), is considered stable if the metacentric height is greater than 1.0 and the deck does not go awash with one cell flooded.

## 650.06 Anchor System

Analyze and design the anchor system using the OPTIMOOR computer program or other suitable mooring software at multiple tide levels using the controlling design vessel parameters and the design impact energy parameters. Use the following criteria to determine the capacity of the anchor system:

- The anchors have a factor of safety of 1.5. The applied anchor force (horizontal and uplift) is less than the ultimate resistance provided by the Geotechnical Recommendations.
- The tension in the mooring chain reaches 40 percent of its breaking capacity (this correlates to a factor of safety of 2.5 and is typical of the industry).

## 650.07 Fender System

Design the fender system to meet the following performance requirements (per fender panel):

- Energy Absorbed, minimum = 150 kip-feet
- Reaction at Rated Energy = 150 kips ( $\pm 10$  percent)
- Deflection at Rated Energy = 50 percent ( $\pm 10$  percent)

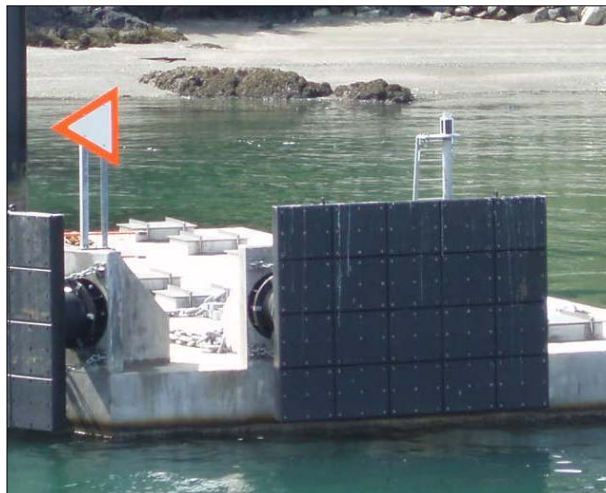
## 650.08 Towing System

Maximum towing load is the minimum of manufacturer's stated cleat capacity or the capacity of the cleat connection to the floating dolphin.

## 650.09 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 650-8](#)).



**Floating Dolphin Navigational Aids**  
*Exhibit 650-8*

## (2) Hatches

Size the pontoon cell hatches to meet all applicable WAC and OSHA requirements as well as to have a diagonal dimension of at least 4.5 feet for the removal of formwork and other equipment from the cells (see [Exhibit 650-9](#)).



**Floating Dolphin Cell Hatch**  
*Exhibit 650-9*

## (3) Ladders

Furnish each floating dolphin with a fixed ladder to provide access to the marine lantern and a portable maintenance ladder located on the pontoon deck to provide access to the cells, both sized to meet all applicable WAC and OSHA requirements (see [Exhibit 650-10](#)).



**Floating Dolphin Portable Ladder**  
*Exhibit 650-10*

**(4) Freeboard**

Design the dolphins for a freeboard of 3.0 feet. The freeboard is measured from the top of the top slab at the edge of the pontoon to the normal water level. The normal water level is to be marked on each side of the pontoon. Calculate the freeboard and draft based on the following criteria:

- Include structure dead load as defined in the [Section 650.04](#).
- Do not include live load.
- Include vertical component of the anchor chain forces.
- Include weight of attachments such as hatches and other hardware.
- The unit weight of seawater as given in [Section 650.04](#).
- Include the weight of reserve ballast equivalent to 3 inches of freeboard to account for construction tolerances and to compensate for potential increases in pontoon draft (loss of freeboard) due to unforeseen weight being added to the dolphin. The final ballast location and amounts are determined by the contractor's naval architect and some adjustments are made in the final placement in the field.
- Include the weight of ballast required to level out (both list and trim) the dolphin.