Section 19 - Piers

19.1 Types

1. Subsection 11.7 of the *AASHTO LRFD Bridge Design Specifications* provides direction on the design of piers.
2. Subsection 5.1 j. of this Manual provides guidance on pier type selections.
3. Designers are strongly encouraged to provide enhancements to the appearance of pier members. This may be accomplished through the use of form liners. As a minimum, form liners will provide architectural treatment of concrete through the use of standard patterns or unique patterns that may be developed for a specific project. Other aesthetic treatments may be recommended.
4. As directed in Subsection 17.1 of this Manual the use of bridge seat pedestals is not permitted.

19.2 Pier Locations

1. Use of corrosion protected reinforcement steel shall be scheduled for, initially, all pier grillage reinforcement steel. Engineering judgment should be used to evaluate the project location toward possibly planning for the use of corrosion protected reinforcement steel for the entire pier construction.

   Such as, when a pier is located in a marine environment (Zone 3A or 3B, See Subsection 24.18.6) then all reinforcement steel (including footing bars and dowels) shall be corrosion protected. To further offset the potential of corrosion development, concrete mix designs for such pier construction may include a corrosion inhibitor admixture.

   If it is determined that a pier or pier element is to be constructed with the use of High Performance Concrete, then the use of a corrosion inhibitor admixture should not be pursued.

   The Designer is advised that epoxy coated, galvanized, stainless steel or stainless steel clad reinforcement are equally permitted.

   If galvanized reinforcement is designated, all surrounding reinforcement and miscellaneous hardware, that is to be in touch with the galvanized reinforcement, must be galvanized, plastic or PVC coated.
2. Steel sheeting below the top of the seal concrete will generally be left in place. If sheeting is left in place it shall be anchored to the top of the seal concrete. Refer to Guide Sheet Plate 3.13-1 when sheeting is to be left in place. Also, refer to Section 33 of this Manual for guidance on the use of steel sheeting.
3. Section 39 of this Manual may be referred to for information regarding scour design, scour protection and pier protection methods.

19.3 Railroads

1. Railroad companies usually require steel sheet piling for excavations adjacent to railroad tracks. The NJDOT Bureau of Civil Engineering should be contacted for specific information regarding these requirements. This information should be obtained prior to the submission of Preliminary Bridge Plans.
2. Piers, that support bridges over railroads and that are located less than 25 feet from the centerline of track, shall either be of solid shaft construction or shall be protected by a reinforced concrete crash wall that extends not less than 7 feet

above the top of rail. This will provide an allowance of 1 foot for future ballasting of the railroad tracks and for potential encroachment during construction or maintenance operations.

The crash wall shall be at least 3’-6” thick and shall connect with all the columns. The face of the crash wall shall extend a distance of at least 6 inches beyond the face of the columns on the side adjacent to the track and it shall be anchored to the columns and footings with adequate steel reinforcement.

For more information, reference Chapter 8, Part 2, Section 2.1.5 of the *AREMA Manual For Railway Engineering*.

3. Footing designs within the theoretical railroad embankment line shall provide a 8 foot minimum distance from any point on the rail to the side of the steel sheet piling used for support of tracks during construction.

19.4 Anchor Bolts

Drilling holes for anchor bolt installation in rigid frame and T-type piers is not permitted. The following steps shall be taken to insure proper construction clearances for anchor bolts (Also see Guide Sheet Plate 3.5-4).

1. Design drawings shall show (in a detail plan and a cross-section view) the relationships between the anchor bolts and the layers of reinforcement steel immediately under each bearing pad. Detail dimensions, locating the centers of the anchor bolts and reinforcement bars shall be indicated.
2. Reinforcement steel adjacent to anchor bolts shall be so spaced as to allow the free installation of 3 inches diameter sleeves for setting anchor bolts.
3. Necessary detail sketches shall be shown to a scale of not less than 1:20. The vertical rows and the horizontal layers of reinforcement steel shall be so spaced as to allow a minimum of 2 diameters clear space between bars to facilitate placing of the concrete.

19.5 Round Columns

1. Spirals shall be used for reinforcement of pier columns. Generally, for the typical grade crossing, 3 foot round columns will be used with 5/8 inch diameter x 3 ½ inch pitch bar for spiral reinforcement. The spiral reinforcing shall be full height of column plus extend into the pier cap and the footing by a minimum of 1’-6” and shall end with 1.5 turns at each end.
2. Guide Plate 3.5-2 provides reinforcement detailing for round columns. Refer to 19.2 above for guidance concerning the use of corrosion protected reinforcement.

19.6 Pile Bents

1. For pile bent type piers, the designer shall establish the minimum pile tip elevation. This elevation shall be shown on the plans.
2. If the structure is located in a severe salt intrusion zone or a salt splash zone, (Zone 3A or 3B as illustrated in the Chart entitled "*Zonal Areas of New Jersey Affected by Salinity*" in Subsection 24.18 of this Manual), all spiral reinforcement for cast-in-place, precast or prestressed concrete pile bents shall be corrosion protected.

In accordance with Table 5.12.3-1 of the *AASHTO LRFD Bridge Design Specifications*, the concrete clear cover for all substructure units that are located in a severe salt intrusion zone or salt splash zone shall be a minimum of 3 inches.

Refer to 19.2 above for guidance concerning the use of corrosion protected reinforcement.

3. Pile bents located in a severe salt intrusion zone or a salt splash zone, as described above, may be constructed with the use of a corrosion inhibitor admixture.

   Refer to 19.2 for guidance concerning the use of High Performance Concrete.

19.7 Abrasion Protection

1. To offset the abrasive action of water or ice against a substructure member High Performance Concrete (HPC) shall be used.

   The entire member can be constructed with HPC or, HPC may be placed with the use of a form liner to provide a protective facing.

   The HPC for pier protection shall meet the performance requirements in the following Table:

Performance Characteristic	Standard Test Method
Abrasion (x = avg. depth of wear in inches)	ASTM C 944
Freeze-Thaw Durability (x = relative dynamic modulus of elasticity after 300 cycles)	AASHTO T 161 ASTM C 666 Proc. A
Chloride Permeability 56 days (coulombs)	AASHTO T 277 ASTM C 1202
56 Day Compressive Strength (Design Compressive Strength)	AASHTO T 22 ASTM C 39

Note: All test to be performed on concrete samples that are moist or submersion cured for 56 days.

2. The Designer should familiarize himself with the required testing and performance requirements. He should also verify inclusion of appropriate specifications for the development of HPC mix designs for the required work in the Contract Documents.

19.8 Fender Pile Systems

In lieu of constructing timber members for fender pile systems, use of FRP composite material may be used for the system components. The increased design life of the composite materials will offset the increased initial cost of the fender system.

The NJDOT Standard Specifications provide criteria for the use of Fiber Reinforced Plastic Lumber (FRLP), Fiber Reinforced Plastic Piles (FRPP) and Fiberglass Concrete

Composite Piles (FCCP). A Designer shall verify the availability of composite pile sizes. This verification should establish that a designated size is available from all approved suppliers. This will avoid restricting a designated size to a sole source supplier.

19.9 Vessel Collision

The design of all bridges over navigable waters in New Jersey must include consideration of possible Vessel Collision. Designers shall conduct a vessel risk analysis to assess the presence of any barge traffic and to determine, if warranted, the most economical method for protecting the bridge. The methodology specified in Subsection 3.14 of the *AASHTO LRFD Bridge Design Specifications* shall be followed for this analysis. The Designer shall also comply with the guidance provided below.

1. To provide a historic basis for the design procedure discussed in Subsection 3.14 of the *AASHTO LRFD Bridge Design Specifications*, information and data shall be gathered as follows:
    a. Data Sources:
        1.) U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center, (www.iwr.usace.army.mil/ndc/csc.htm). Commerce statistics for the subject bridge.
        2.) Port Authorities and Water Dependent Industries. Data to document use of the bridge locations by such groups.
        3.) Pilot Associations and Merchant Marine Organizations. Data to document use of the bridge locations by such groups.
        4.) National Oceanic and Atmospheric Administration (NOAA), Tidal Current Tables; Tidal Current Charts and Nautical Charts. (www.noaa.gov/charts.html)
        5.) Bridge Tender records for bascule bridge at Regional Offices.
        6.) Local tug and barge companies.
    b. Assembly of Information unless provided by the Department:
        1.) Characteristics of the waterway including the following:
            a.) Nautical chart of the waterway.
            b.) Type and geometry of bridge.
            c.) Preliminary plan and elevation drawings depicting the number, size and location of the proposed piers.
            d.) Navigation channel, width, depth and geometry.
            e.) Average current velocity across the waterway.
        1.) Characteristics of the vessels and traffic including the following:
            a.) Ship, tug and barge sizes (length, width and height).
            b.) Number of passages for ships, tugs and barges per year (last five years and prediction to end of 25 years in the future).
            c.) Vessel displacements.

d.) Cargo displacements (deadweight tonnage).

e.) Draft (depth below the waterline) of ships, tugs and barges.

f.) The overall length and speed of tow.

c. Accident reports

d. Bridge Importance Classification

2. Importance Category (IC)

Generally, the Importance Classification (IC) for bridges crossing a navigable waterway shall be that of "Regular". However, the Designer shall evaluate project specific conditions to determine the Social Survival and Security/Defense requirements of such bridges. If deemed appropriate, the Designer may recommend to the Manager, Structural Engineering, that the bridge be evaluated under an IC of "Critical".

3. Design Vessel

Subsection 3.14.1 of the *AASHTO LRFD Bridge Design Specifications* specifies the parameters to define the minimum design barge.

Subsection 3.14.4 of the *AASHTO LRFD Bridge Design Specifications* provides guidance for the selection of design vessels for specific bridge piers. Based on an analysis of the annual frequency of collapse, a design vessel and its associated collision loads can be determined.

4. Design Methodology

Subsection 3.14.15 of the *AASHTO LRFD Bridge Design Specifications* provides guidance for the design of a substructure protection system. The protection system shall be designed to stop or redirect a vessel so that the substructure member is not impacted.

NJDOT conducted a research project that identifies Energy Absorbing Fender Systems. The final report should be studied to facilitate identification of such systems. The Report, numbered FHWA NJ 2003-11, dated July, 2003 can be downloaded from the following website link:

www.state.nj.us/transportation/refdata/research.

Bridge piers that are not in the main channel may be designed for a reduced impact. This is considerate of a vessel's ability to attain sufficient water draft to permit it to strike a pier that is not in the main channel. If such an occurrence is not possible, then no impact force shall be applied.

In addition to utilizing the design specifications presented in the *LRFD Bridge Design Specifications*, the Designer shall also follow the following design methodology:

a. At least one iteration of secondary effects in columns shall be included; i.e., axial load times the initial lateral deflection.

b. The analysis must include the effect on adjacent piers from the transfer of lateral forces up to the superstructure. Bearings, including neoprene pads, may transfer lateral forces to the superstructure. Analysis of forced transfer through the mechanisms at the superstructure/substructure interface shall be evaluated by use of generally accepted theory and practice.

c. The capacity of axially loaded piles shall be limited to the determined compressive and/or tensile loads. For battered pile foundations, load redistribution shall not be permitted when this capacity is reached.

d. Lateral soil-pile response shall be determined by concepts utilizing a coefficient of subgrade modulus.

e. Load Combination “Extreme Event II” shown in Table 3.4.1-1 of the *AASHTO LRFD Bridge Design Specifications* shall be used for Vessel Collision. Nonlinear structural effects shall be included and can be significant, particularly for the pier components.

f. If it is determined that a superstructure member could be impacted by a waterway vessel, the corresponding superstructure span shall be designed for ultimate lateral strength under a ship mast impact force in accordance with the *AASHTO LRFD Bridge Design Specifications*. There shall be no redistribution of the vehicle collision force between piers throughout the superstructure.

5. Pile Bents

Bridges in navigable waterways with pile bents shall be designed to remain open for traffic after a vessel collision even if any one pile is lost as a result of the collision. For this design, the load combination for Extreme Event II shall apply; however, the Load Factor for Live Load shall be increased to 1.0.

6. Movable Bridges

Movable bridges shall comply with the Vessel Collision requirements stated herein without exception.

7. Main Span Length for Barges

The length of the main span between centerlines of piers at the navigable channel shall be based upon Coast Guard requirements, the Vessel Collision risk analysis (in conjunction with a least-cost analysis) and aesthetic considerations.

8. Scour with Vessel Collision

The probability of the simultaneous occurrence of a Vessel Collision impact and the presence of scour is a valid concern when planning the design of a substructure’s foundation. For this reason, the foundation shall be designed to withstand the following two Load/Scour (LS) combinations:

A. Load/Scour Combination 1:

$LS_{(1)}$ = Vessel Collision + ½ Long-Term Scour

Where:

Vessel Collision: Assumed to occur at normal operating speed.

Long-Term Scour: Defined in Section 39 of this Manual.

B. Load/Scour Combination 2:

$LS_{(2)}$ = Minimum Impact Vessel + ½ 100-Year Scour

Where:

Min. Impact Vessel: Defined in Subsection 3.14.1 of the LRFD Specifications

100-Year Scour: Defined in Section 39 of this Manual.

When preparing the soil models for computing the foundation strengths, and when otherwise modeling stiffness, the Designer must exercise judgment in assigning soil strength parameters to the soil depth that is subject to Local and Contraction Scour and that may have filled back in.

The soil model shall utilize strength characteristics over the depths that are compatible with the type soil that would be present after having been hydraulically redeposited. In many cases, there may be little difference between the soil strength of the natural stream bed and that of the soil that is redeposited subsequent to a scour event.

9. Application of Impact Forces

For long narrow footings in the waterway when the length to width ratio, L/W, is 2.0 or greater, the longitudinal force shall be applied within the limits of the distance that is equal to the length minus twice the width (L-2W).