Section 16 - Foundations Design Criteria

Section 10 - Foundations of the *AASHTO LRFD Bridge Design Specifications* shall be followed for the design of foundations.

Additionally, the following guidance is provided to assist Designers in utilizing the AASHTO LRFD Specifications:

16.1 Determination of Soil Properties

Subsurface exploration and soil tests shall be performed in accordance with Subsection 10.4 of the *AASHTO LRFD Bridge Design Specifications* (with current interims) and the criteria established in Section 34 of this Manual.

16.2 Loads

1. Mass Density (Unit Weight) of Soil ……..…….. 120 lbs/cu.ft
2. Mass Density (Unit Weight) of Concrete ……..…...150 lbs/cu.ft
3. Surcharge loads shall be based on the criteria that is stated in Subsection 3.11.6 of the AASHTO LRFD Bridge Design Specifications.
4. To consider the vertical load per foot of approach slabs that react on the abutment backwall, 1/3 of the approach slab length shall be assumed to cause reactions onto the abutment. Also reference Subsection 17.2.7 of this manual
5. Compaction induced additional earth pressures, that are due to construction equipment, shall be considered. Subsection 3.11.2 of the *AASHTO LRFD Bridge Design Specifications* should be referred to for guidance in estimating such earth pressures.

16.3 Foundations

In order to prevent damage from frost heave, footings shall be founded at an elevation that is a minimum of 4 feet below the existing ground line or, other than when founded on sound rock, shall be embedded a sufficient depth to provide adequate bearing, scour and frost heave protection, whichever is greater.

Also, refer to Section 39 of this Manual for guidance concerning scour considerations.

1. Spread Footings
   a. The minimum footing thickness shall be 2 feet.
   b. Passive resistance shall be disregarded in sliding failure determination.
   c. Top heel steel shall be designed to support all superimposed loading plus the dead load of the footing. This is without reduction from minimum upward soil pressure that acts beneath the heel.
   d. Toe steel design shall be based upon a cantilever design with earth pressure acting upward and the dead load of concrete acting downward.
   f. Eccentricity of Loads
      1.) When foundations are on soil, the bearing resistance shall be determined in accordance with subsection 10.6.3.1 of the *AASHTO LRFD Bridge Design Specifications*.

2.) When footings are founded on rock, the eccentricity of loading shall not exceed 3/8 of the width or length. (See Subsection 10.6.3.3 of the *AASHTO LRFD Bridge Design Specifications*.)

2. Pile Foundations

   a. The minimum pile cap thickness shall be 3 feet.

   b. Material for steel H-piles shall conform to AASHTO M270 Grade 50. Steel H-piles for use in marine environments shall conform to AASHTO M270, Grade 50. All exposed surface areas and those that are within 2 feet of the mudline shall be coated with a 16 mil application of coal tar epoxy as per SSPC Paint Specification 16.

      The minimum steel H-pile section for use in pile foundations shall be 12 inches.

      In locations where steel piling or steel shells may be subjected to abrasive actions of the bed load of materials, an increased effective section is to be considered in the pile size selection.

   c. The use of timber piles should be evaluated against current environmental regulations on the use of treated timber. Environmental restrictions may preclude the use of any treated timber product.

   d. The following criteria, concerning pile foundation design and construction requirements, shall be indicated as Foundation Design Criteria General Notes on the Preliminary and Final Bridge Plans:

      1.) Pile type, size, and the associated material properties

      2.) Nominal Axial Compression Resistance

      3.) Factored Axial Compression Resistance

      4.) Nominal Uplift Resistance

      5.) Factored Uplift Resistance

      6.) Required Driving Resistance for Determination of the Bearing Value using PDA and CAPWAP

      7.) Required Resistance for Wave Equation Analysis Program (WEAP) Analysis of the Pile Driving System

      8.) Estimated Pile Tip Elevation

      9.) Minimum Pile Tip Elevation (only specified if necessary)

   e. The Standard Specifications require that the Contractor submit a completed "Pile and Driving Equipment Data Form" and wave equation analysis using WEAP to demonstrate that piles can be driven with reasonable effort to the ordered lengths and without damage.

      Also, the Contractor is to conduct PDA measurements and a CAPWAP analysis for designated piles, or as may be directed by the Resident Engineer (RE).

   f. Designers shall be aware of the Standard Specifications requirements in advancing the design of a pile foundation design. To facilitate this, the following guidance shall be followed:

      1.) Resistance Factor Determination

Test piles are required to be monitored with PDA and CAPWAP. A resistance factor as specified in Subsection 10.5.5.2.3 of the *AASHTO LRFD Bridge Design Specifications* should be used.

2.) Required Resistance for PDA

Generally this value should be equal to the value of Nominal Axial Compression Resistance. However, if a minimum pile tip elevation is required, the value that accounts for the driving resistance of the layers that are not to be considered for the permanent bearing resistance, could be higher.

3.) Required Resistance for WEAP

Generally this value should be equal to the resistance required for the PDA. However, if a hard layer is required to be driven through, the resistance for the WEAP could be higher. If this is the case, the Required Driving Resistance for PDA shall be used for the bearing value determination during pile driving.

4.) Minimum Pile Tip Elevation

If required, a minimum pile penetration should only be specified to ensure that all of the applicable limit states are met; e.g., lateral deflection, uplift, scour, downdrag and pile group settlement. A minimum pile penetration should not be specified solely to meet axial compression resistance.

g. Refer to Guide Plate 3.4-6 for guidance on test pile plan designations. In establishing estimated test pile lengths, the total length that is provided for bidding purposes should be considerate of potential variant lengths of each test pile location. That is, the length of each test pile should not be based on an averaging of length per test pile.

h. When use of prestressed concrete piles are planned and they are to be constructed in a marine environment, grit impregnated epoxy coated prestressing steel strands shall be used. The grit impregnated epoxy coated prestressing steel strands shall conform to the requirements of ASTM A882.

Low relaxation prestressing strands shall be used for all prestressed concrete pile applications.

i. The effects of scour must be considered in addressing pile type selection.

j. When selecting concrete filled pipe piles, the effective depth of the concrete must be considered in regard to structural capacity.

3. Prestressed/Precast Concrete Piles

Class P Concrete

Class P Concrete with corrosion inhibitors shall be required for buried piles.

High Performance Concrete (HPC)

Use of HPC is based on the following conditions:

a. Prestressed or Precast concrete piles that are to be used in environmentally aggressive conditions (such as exposure to tidal areas). Use of HPC will optimize the expected durability and performance of the prestressed/precast

concrete piles. Performance measures such as permeability and abrasion resistance will better assure the expected service life of such pile systems. When such performance is desired, HPC should be used. The strength requirements shall be determined by the Designer based on Section 27 of this manual for class of concrete.

b. A concrete pile that requires a design compressive strength greater than f'c=6000 psi should be designed as an HPC element.

c. Use the following criteria to develop an HPC mix design. Establish the Specific Performance Requirements in the Project's Special Provisions.

Performance Characteristic	**Standard Test Method**
Creep @ 180 days (x=microstrain/pressure unit)	ASTM C 512
Modulus of Elasticity	ASTM C 469
Chloride Permeability 56 days	AASHTO T 277
Shrinkage (x=length change in microstrain)	ASTM C 157
56 Day Compressive Strength	AASHTO T 22
Abrasion Resistance (x= average depths of wear)	ASTM C 944

Notes:

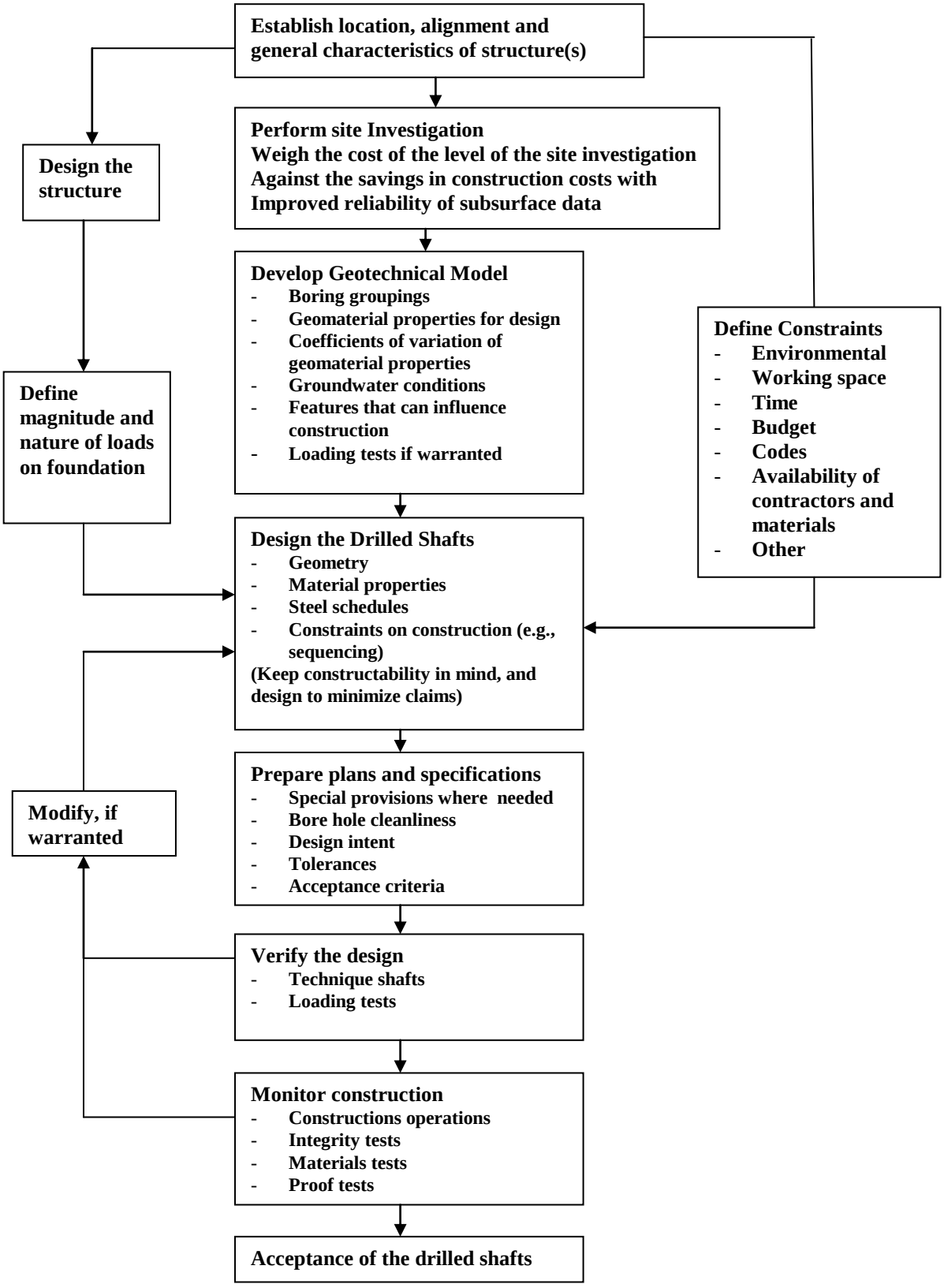
1. Acceptance of HPC pile systems shall be based on achieving the design compressive strength required in a Project.
2. Chloride permeability testing and Abrasion Resistance testing will only be required when precast or prestressed concrete piles are to be submerged in water as pier bent members.
3. All tests will be performed on samples that are moist cured for 56 days.

4. Drilled Shaft Foundations

a. The obtained axial loading shall be used to design the depth and diameter of the shaft, steel reinforcement and concrete.

b. The Federal Highway Administration Publication Number FHWA-IF-99-025, titled "*Drilled Shafts: Construction Procedures and Design Methods*" may be studied for assistance in designing drilled shafts.

c. The following flow chart illustrates the overall process of designing and constructing drilled shafts:


Establish location, alignment and general characteristics of structure(s)
Perform site Investigation
Weigh the cost of the level of the site investigation
Against the savings in construction costs with
Improved reliability of subsurface data
Design the structure
Develop Geotechnical Model
- Boring groupings
- Geomaterial properties for design
- Coefficients of variation of geomaterial properties
- Groundwater conditions
- Features that can influence construction
- Loading tests if warranted
Define Constraints
- Environmental
- Working space
- Time
- Budget
- Codes
- Availability of contractors and materials
- Other
Define magnitude and nature of loads on foundation
Design the Drilled Shafts
- Geometry
- Material properties
- Steel schedules
- Constraints on construction (e.g., sequencing)
(Keep constructability in mind, and design to minimize claims)
Prepare plans and specifications
- Special provisions where needed
- Bore hole cleanliness
- Design intent
- Tolerances
- Acceptance criteria
Modify, if warranted
Verify the design
- Technique shafts
- Loading tests
Monitor construction
- Constructions operations
- Integrity tests
- Materials tests
- Proof tests
Acceptance of the drilled shafts

d. The Designer shall be cognizant that the initial design may, due to conditions encountered in the field, require modifications. As such, the Designer should be prepared to respond to this requirement.

e. When drilled shafts, that are constructed in moderately or extremely aggressive environments and that extend through water, are used in bents, they shall be detailed to eliminate construction joints within the Splash Zone. Additionally, it is preferred that such shafts extend to the bottom of the bent cap without a construction joint.

5. Foundation Tolerable Movements

   a. Movements that must be addressed in a foundation's design shall include those of vertical, horizontal and rotational.

   b. As controlling parameters, a foundation is to be designed to provide a total and differential settlement of one (1) inch. If the one inch requirement results in significant cost to the detailing of the superstructure, designing for provision of an efficient total settlement that is greater than one inch may be pursued. The NJDOT Geotechnical Engineering Unit should be contacted for concurrence as to a recommended settlement value.

6. Self Consolidating Concrete (SCC). Use of Self Consolidating Concrete (SCC) is permitted for drilled shaft construction. Use of SCC has proven to be successful in addressing concrete consolidation concerns. The NJDOT Standard Specifications can be referred for criteria on the use of SCC.

16.4 Additional Conditions

Additional conditions to consider for stability of the structure should be checked in terms of:

1. Maximum acceptable post construction settlement.
2. Foundation soil's stabilization for minimum residual settlement.
3. Overall earth mass stability of the foundation soils and/or embankment supporting the structure.
4. Consideration of soil characteristics on the post construction effect on pile foundations (drag and additional lateral pressure).

16.5 Prestressed Concrete Pile Connections

1. In order to account for the potential uplift of prestressed concrete piles, details to provide for a connection between the pile and pile cap shall be developed and provided in the final plans.
2. The use of mild steel dowels shall be planned for to provide this connection. Details to indicate field drilling and grouting of inserted dowels shall be provided. The size of the dowels and their length shall be as determined by design.