SECTION 7 - SUBSTRUCTURES

Part A
General Requirements and Materials

7.1 GENERAL

7.1.1 Definition

A substructure is any structural, load–supporting component generally referred to by the terms abutment, pier, retaining wall, foundation or other similar terminology.

7.1.2 Loads

Where appropriate, piers and abutments shall be designed to withstand dead load, erection loads, live loads on the roadway, wind loads on the superstructure, forces due to stream currents, floating ice and drift, temperature and shrinkage effects, lateral earth and water pressures, scour and collision and earthquake loadings.

7.1.3 Settlement

The anticipated settlement of piers and abutments should be estimated by appropriate analysis, and the effects of differential settlement shall be accounted for in the design of the superstructure.

7.1.4 Foundation and Retaining Wall Design

Refer to Section 4 for the design of spread footing, driven pile and drilled shaft foundations and Section 5 for the design of retaining walls.

7.2 NOTATIONS

The following notations shall apply for the design of pier and abutment substructure units:

B = Width of foundation (ft)
e = Eccentricity of load from foundation centroid in the indicated direction (ft)
H = Height of abutment (ft)

The notations for dimension units include the following: ft = foot. The dimensional units provided with each notation are presented for illustration only to demonstrate a dimensionally correct combination of units for the design procedures presented herein. If other units are used, the dimensional correctness of the equations should be confirmed.

Part B
Service Load Design Method
Allowable Stress Design

7.3 PIERS

7.3.1 Pier Types

7.3.1.1 Pier Walls

Pier walls are designed as columns for forces and moments acting about the weak axis and as piers for those acting about the strong axis. Pier walls are defined as a bridge support system consisting of a wall on a footing or piles. Ratio of clear height to maximum width is less than 2.5.

7.3.1.2 Double Wall Piers

More recent designs consist of double walls, spaced in the direction of traffic, to provide support at the continuous soffit of concrete box superstructure sections. These walls are integral with the superstructure and must also be designed for the superstructure moments which develop from live loads and erection conditions.

7.3.1.3 Bents

Bents are a bridge support system consisting of one or more columns supporting a single cap. Columns are defined as a single support member having a ratio of clear height to maximum width of 2.5 or greater. The columns may be supported on a spread- or pile-supported footing, or a solid wall shaft, or they may be extensions of the piles or shaft above the ground line.

+ **7.3.1.4** *Deleted*

7.3.2 Pier Protection

7.3.2.1 Collision

Where the possibility of collision exists from highway or river traffic, and appropriate risk analysis should be made to determine the degree of impact resistance to be provided and/or the appropriate protection system.

7.3.2.2 Collision Walls

Collision walls extending 6 feet above top of rail are required between columns for railroad overpasses, and similar walls extending 2.35 feet above ground should be considered for grade separation structures unless other protection is provided.

7.3.2.3 Scour

The scour potential must be determined and the design must be developed to minimize failure from this condition.

7.3.2.4 Facing

Where appropriate, the pier nose should be designed to effectively break up or deflect floating ice or drift. In these situations, pier life can be extended by facing the nosing with steel plates or angles, and by facing the pier with granite.

7.4 TUBULAR PIERS

7.4.1 Materials

Tubular piers of hollow core section may be of steel, reinforced concrete or prestressed concrete, of such cross section to support the forces and moments acting on the elements.

7.4.2 Configuration

The configuration can be as described in Article 7.3.1 and, because of their vulnerability to lateral loadings, shall be of sufficient wall thickness to sustain the forces and moments for all loading situations as are appropriate. Prismatic configurations may be sectionally precast or prestressed as erected.

7.5 ABUTMENTS

7.5.1 Abutment Types

7.5.1.1 Seat Type Abutment +

Seat type abutments are located at or near the top of approach fills, with a backwall depth sufficient to accommodate the structure depth and bearings which sit on the bearing seat. +

7.5.1.2 Partial-Depth Abutment

Partial-depth abutments are located approximately at mid-depth of the front slope of the approach embankment. The higher backwall and wingwalls may retain fill material, or the embankment slope may continue behind the backwall. In the latter case, a structural approach slab or end span design must bridge the space over the fill slope, and curtain walls are provided to close off the open area. Inspection access should be provided for this situation.

7.5.1.3 Full-Depth Abutment

Full-depth abutments are located at the approximate front toe of the approach embankment, restricting the opening under the structure.

7.5.1.4 Diaphragm Abutment +

Diaphragm abutments are rigidly attached to the superstructure and are supported on spread or deep foundations capable of permitting necessary horizontal movements. +

7.5.2 Loading

Abutments shall be designed to withstand earth pressure as specified in Article 5.5 and 5.6, the weight of the abutment and bridge superstructure, live load on the superstructure or approach fill, wind forces and longitudinal forces when the bearings are fixed, and longitudinal forces due to friction or shear resistance of bearings. The design shall be investigated for any combination of these forces which may produce the most severe condition of loading. Diaphragm abutments must be designed for forces generated by thermal movements of the superstructure.

7.5.2.1 Stability

Abutments shall be designed for the loading combination specified in Article 3.22.

- Abutments on spread footings shall be designed to resist overturning (FS $\geq$ 2.0) and sliding (FS 1.5). Dead and live loads are assumed uniformly distributed over the length of the abutment between expansion joints.
- Allowable foundation pressures and pile capacities shall be determined in accordance with Articles 4.4 and 4.3.
- The earth pressures exerted by fill in front of the abutment shall be neglected.
- Earth pressures when active wedge cannot occur (i.e. strutted abutments) should be addressed in Section 5.
- The earth pressures exerted by the fill material shall be calculated in accordance with Articles 5.5.2 and 5.6.2.
- The cross section of stone masonry or plain concrete abutments shall be proportioned to avoid the introduction of tensile stress in the material.

7.5.2.2 Reinforcement for Temperature

Except in gravity abutments, not less than 1/8 square inch of horizontal reinforcement per foot of height shall be provided near exposed surfaces not otherwise reinforced to resist the formation of temperature and shrinkage cracks.

7.5.2.3 Drainage and Backfilling

The filling material behind abutments shall be free draining, nonexpansive soil, and shall be drained by weep holes with French drains placed at suitable intervals and elevations. Silts and clays shall not be used for backfill.

7.5.3 Diaphragm Abutments

Diaphragm abutments shall be designed to resist the forces generated by thermal movements of the superstructure against the pressure of the fill behind the abutment. Diaphragm abutments should not be constructed on spread footings founded or keyed into rock. Movement calculations shall consider temperature, creep, and long-term prestress shortening in determining potential movements of abutments.

Maximum span lengths, design considerations, details should comply with recommendations outlined in FHWA Technical Advisory T 5140.13 (1980) except where substantial local experience indicates otherwise.

To avoid water intrusion behind the abutment, the approach slab should be connected directly to the abutment (not to wingwalls), and appropriate provisions should be made to provide for drainage of any entrapped water.

7.5.4 *Deleted*

7.5.5 *Deleted*

7.5.6 Wingwalls

7.5.6.1 Length

Wingwalls shall be of sufficient length to retain the roadway embankment to the required extent and to furnish protection against erosion. The wingwall lengths shall be computed using the required roadway slopes.

7.5.6.2 Reinforcement

Reinforcing bars or suitable rolled sections shall be spaced across the junction between wingwalls and abutments to tie them together. Such bars shall extend into the masonry on each side of the joint far enough to develop the strength of the bar as specified for bar reinforcement, and shall vary in length so as to avoid planes of weakness in the concrete at their ends. If bars are not used, an expansion joint shall be provided and the wingwall shall be keyed into the body of the abutment.

Part C
Strength Design Method
Load Factor Design

7.6 *Deleted*