

SECTION 5
ABUTMENTS, PIERS AND WALLS

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SECTION 5 **ABUTMENTS, PIERS AND WALLS**

5.1 GENERAL

5.1.1 Abutments

An abutment supports the end of a bridge span, provides lateral support for approach roadway fill and supports the approach roadway and approach slab. Abutments may be described by their location relative to the approach embankments.

A stub (embankment) abutment is located at or near the top of the approach fill. A partial depth abutment is located approximately mid-depth of the front slope of the approach embankment. A full depth (shoulder) abutment is located at the approximate toe of the approach embankments.

Abutment types shall be selected considering structure aesthetics, foundation recommendations, structure location, and the loads it must transmit to the foundation. For structures over waterways, the abutment type and location should also be specified with consideration to hydraulic conditions at the site. Wherever possible, use stub (embankment) abutments for structures over waterways.

The acceptable abutments types include non-proprietary systems such as gravity walls, cantilever walls, counterfort walls and integral abutments. Preference shall be given to integral abutments. Abutments shall not be placed on fill supported by mechanically stabilized earth walls or prefabricated modular walls, except for Geosynthetic Reinforced Soil-Integrated Bridge Systems. Generally, for abutments and wingwalls founded on rock, where the footings are exposed, the abutment and wingwalls shall be designed without a toe.

5.1.2 Piers

A pier provides intermediate support between the superstructure and the foundation. Pier types shall be selected considering structure aesthetics, foundation recommendations, structure location, and the loads it must transmit to the foundation. If possible, on large projects with many piers, the type of pier shall be consistent throughout the entire project for reasons of economy. The acceptable concrete pier types include wall piers, open column bents, multiple column piers, and single column piers. The use of permanent steel pier bents is discouraged due to future maintenance.

5.1.3 Walls

Walls should be used where the construction of a roadway or facility cannot be accomplished with slopes. Walls can be classified as either retaining walls, or wingwalls. Wingwalls are used to provide lateral support for the bridge approach roadway embankment. For bridges

with long wingwalls that are parallel to the roadway, the wingwall shall be referred to as a retaining wall and may receive a wall number.

Wingwalls shall preferably be U-type (parallel to the roadway). Flared wingwalls are permitted where conditions warrant such as for hydraulic performance of waterway crossings. The acceptable wingwall types include non-proprietary systems such as gravity walls, cantilever walls and counterfort walls. Proprietary systems, such as mechanically stabilized earth and prefabricated modular walls, shall only be used for retaining walls.

Retaining walls may be non-proprietary systems such as gravity walls, cantilever walls, counterfort walls or tie-back walls, or may be proprietary systems such as mechanically stabilized earth walls or prefabricated modular walls.

The tops of retaining walls shall not be determined by the exact fill slope but shall follow a smooth unbroken line for a more pleasing appearance. This may require the use of vertical curves, in which case elevations shall be given at 5 foot intervals.

5.1.4 Foundations

A foundation serves to transmit the forces acting on the abutments, piers, or walls into the ground. Foundations are classified as either shallow or deep. A shallow foundation derives its support by transferring load directly to soil or rock at a shallow depth. Spread footings are shallow foundations. A deep foundation derives its support by transferring loads to soil or rock at some depth below the structure by end bearing, adhesion or friction or both. Driven piles, micropiles and drilled shafts are deep foundations.

Foundation type is generally based on the anticipated (structure) loads, underlying soil conditions, scour potential, and site constraints along with the ease and cost of construction.

5.2 IDENTIFICATION NUMBERS

All abutments and piers shall be identified by numbers which start with the number “one” and progress consecutively but separately in the direction of stationing of the roadway, such as, Abutment 1, Pier 1, Abutment 2, etc.

All wingwalls shall be identified by a combination of a number and a letter (alphanumeric), such as 1A or 1B. The number used must correspond to the abutment to which the wingwall is attached. Looking up station, the letter “A” indicates the wingwall is on the left and the letter “B” indicates the wingwall is on the right.

Retaining walls shall be identified by three numbers that start at 101 and progress consecutively in the direction of stationing of the roadway, such as Retaining Wall 101, Retaining Wall 102. Parallel walls along both edges of roadway beginning at the same station are to follow wingwall rules. These numbers may designate a proprietary wall, a proprietary embankment wall, a cast-in-place wall or a soil nail wall. A table shall be provided in the contract identifying the relationship between the wall number, type and site number of the wall, and location as in the following:

RETAINING WALL NUMBER	DESCRIPTION	LOCATION
101	Embankment Wall – Site 1	Station 10+00 to 12+50
102	Retaining Wall – Site 2	Station 25+50 to 32+50
103	Cast-in-place – Site 3	Station 70+00 to 72+50
104	Retaining Wall – Site 4	Station 80+00 to 82+50

5.3 EXCAVATION

5.3.1 General

Contract items for structure excavation, unless the work is included under other items, are required for the removal of all material of whatever nature necessary for the construction of foundations for bridges, box culverts, retaining walls and other structures. The items specified in the contract depends on the type of material removed, earth or rock, and whether or not separate payment will be made for the work related to cofferdams and dewatering.

On any project where only some of the structures and/or their components require cofferdams and some do not, a combination of structure excavation items shall be shown in the contract. The contract for the structures and components requiring “Cofferdam and Dewatering” shall clearly delineate the pay limits and the limits of the cofferdam.

5.3.2 Construction Requiring Cofferdam and Dewatering

A cofferdam is a structure that retains water and soil that allows the enclosed area to be pumped out and excavated dry to permit construction.

At water crossings, where structures or their components are located partially or wholly in the water and the bottom of the footing is below water level, or where a considerable flow or concentration of water is present that cannot be diverted, partly or wholly, from the site, the contract shall include the following item:

ITEM NAME	PAY UNIT
Cofferdam and Dewatering	L.F.

The hydraulic design of the cofferdam should be done in accordance with the **Drainage Manual**.

The contract shall also include either one or both of the following items, as required for the type of material removed:

ITEM NAME	PAY UNIT
Structure Excavation – Earth (Excluding Cofferdam and Dewatering)	C.Y.
Structure Excavation – Rock (Excluding Cofferdam and Dewatering)	C.Y.

Where underwater (tremie) concrete may be used to seal the bottom of a cofferdam to allow dewatering, the weight of the tremie concrete, adjusted for buoyancy, shall be added to pile and foundation loads for design purposes.

5.3.3 Construction in the Dry

Where structures or their components are to be constructed in the dry or where water may be temporarily directed away from an excavation, eliminating the need for a cofferdam, the contract shall also include either one or both of the following items, as required for the type of material removed:

ITEM NAME	PAY UNIT
Structure Excavation – Earth (Complete)	C.Y.
Structure Excavation – Rock (Complete)	C.Y.

The temporary redirection of water or water courses, either partially or wholly, from an excavation or site, must be coordinated with hydraulic studies and DEEP, Federal and State permit submittals. At the sites where water is directed away from an excavation, the following item shall be included in the contract.

ITEM NAME	PAY UNIT
Handling Water (Site No.)	L.S.

5.4 EXPANSION, CONTRACTION AND CONSTRUCTION JOINTS

Expansion and contraction joints in concrete abutment and wall stems shall be provided in accordance with **LRFD**. Construction joints shall be placed as conditions warrant. Construction joints other than those shown in the contract require prior approval from the Engineer. Expansion or contraction joints should not be provided in footings. Footings for abutments and walls should be continuous including any steps provided.

No reinforcement shall pass through expansion and contraction joints. Reinforcement shall pass through construction joints.

5.5 DAMPPROOFING

The rear face of cast-in-place and precast abutments and wall stems shall be damp- proofed.

5.6 BACKFILL REQUIREMENTS

5.6.1 General

Unless otherwise directed, all abutments, wingwalls and retaining walls shall be backfilled with Pervious Structure Backfill to the limits described below. Pervious Structure Backfill is a clean, granular soil. For design purposes, the effective angle of internal friction shall be taken as equal to 35 degrees.

5.6.2 Backfill Limits

Indicate a wedge of Pervious Structure Backfill above a slope line starting at the top of the heel and extending upward at slope of 1:1½ (rise to run) to the bottom of the subbase. In cut situations, the following note, with a leader pointing to the slope line, shall be placed in the contract:

Slope line except where undisturbed material obtrudes within this area.

5.7 SUBSURFACE DRAINAGE (Rev. 04/19)

5.7.1 General

Subsurface drainage shall be accomplished with the use of weepholes extending through the wall stems, or underdrains placed along the wall stems. Subsurface drainage for proprietary retaining walls shall conform to the owned special provisions governing their design and construction.

5.7.2 Weepholes and Bagged Stone

Except for structures placed on embankments, 4 inch diameter weepholes, sloped 1:8 (rise to run), shall be placed approximately 1 foot above the finished grade at the front face of the wall stem. For structures placed on embankments, the weepholes shall be extended through the slope with an outlet. Weepholes shall not drain onto adjacent sidewalks. Weepholes should be spaced at approximately 8 to 10 foot intervals unless conditions warrant a closer spacing. The spacing and invert elevations of the weepholes shall be shown in an elevation view.

The cost of furnishing and installing weepholes is included in the cost of the concrete. Bagged Stone is paid under “Pervious Structure Backfill”.

5.7.3 Underdrains and Outlets (Rev. 04/19)

Underdrains shall have a 6 inch nominal diameter, perforated and placed at the base of the stem and sloped a minimum of 1%. Underdrains shall be either connected to the roadway drainage or to a free outlet. The location and limits of the underdrain shall be shown in plan view. The invert elevations shall be shown in an elevation view. Outlets for underdrains shall consist of

pipe laid in a trench and refilled with earth. The size and type of outlet pipe shall be the same as that of the underdrain to which it is connected, except that it shall not be pervious to water.

Underdrains shall be paid for under the item “6 inch Structure Underdrain”. Outlets shall be paid under “6 inch Outlets for Underdrain”. When an underdrain is connected to the roadway drainage, the pipe beyond the face of the wall stem or the end of the wall shall be shown in the contract to be included in the roadway items, and should be coordinated with the roadway designer.

5.7.4 Subsurface Drainage Selection Criteria

5.7.4.1 Full Height Abutments

At abutments in cut situations, either an underdrain or weepholes may be used with the latter being preferred. Weepholes should be used at abutments located on fills. When there is a sidewalk in front of any abutment, an underdrain should be used. Where this type of abutment is used at water crossings, drainage shall be provided by weepholes.

5.7.4.2 Perched Abutments

At abutments in wet cuts, an underdrain should be used. At abutments in dry cuts and fills, extended weepholes should be used. If the total length of the extended weepholes exceeds what’s required for underdrains, the latter is preferred.

For walls with a fully exposed face adjacent to a sidewalk, an underdrain should be used. For walls with a fully exposed face not adjacent to a sidewalk, weepholes should be used. For walls with a partially exposed face, an underdrain should be used.

5.8 APPROACH SLABS (Rev. 04/19)

Approach slabs shall be provided on all bridges carrying State highways. Approach slabs shall be strongly considered on all bridges undergoing superstructure replacement and local road bridges.

Approach slabs should extend the full width of the roadway (including shoulders), have a standard length of 16 feet and be 1.25 feet thick. Generally, approach slabs should follow the skew of the bridge for skew angles up to 35 degrees. For skew angles greater than 35 degrees, the ends of the approach slabs should be square to the roadway with a minimum length of 15 feet. Acute corners of approach slabs and approach pavement should be squared off for a distance of five feet from the gutter line. Approach slabs shall be anchored to the bridge abutment.

Approach slabs shall be constructed in accordance with **BDM** [6]. Approach slabs shall be covered with a waterproofing membrane and a bituminous concrete overlay. All the material items used in the construction of the approach slabs, including the overlay, shall be included in the structure items and quantities.

All elevations necessary for construction of the approach slabs shall be shown in the contract. These elevations shall include the elevations at the point of application of grade line, the gutter lines and at shoulder break lines at both ends of the approach slabs.

5.9 SLOPE PROTECTION

Provisions shall be made for protection of earth slopes in front of abutments on bridges over State highways, local roads, railroads and waterways. The slope of the embankment in front of the abutment shall be no steeper than 1:2 (rise to run).

5.9.1 Selection Criteria

The type of slope protection shall generally conform to the following criteria:

- Crushed Stone for Slope Protection shall be used under structures overpassing Interstate highways, railroads and waterways. Protection between the edge of the shoulder and the toe of the slope should be founded on a 6 inch granular fill base or geotextile. The limits of this base should be shown in the contract and shall be include in the estimated structure quantities.
- Concrete Block Slope Protection shall be used under structures overpassing State highways and local roads. The block shall be anchored or mortared into place to prevent vandalism. The use of granite block is not permitted due to its higher cost. Cast-in-place concrete is not permitted due to cracking and settlement of existing installations.
- Abutment slope protection for bridges over waterways should be designed in accordance with the procedures outlined in **HEC-18** or successor documents as well as documents referenced therein.

5.9.2 Limits of Slope Protection

The limits of slope protection shall cover the complete area, exclusive of sidewalks, from the edge of the shoulder to the face of the abutment stem and transversely within lines parallel to and 2 feet outside of the bridge rails.

5.9.3 Inspection Shelf

Provisions for inspection access (for bridge inspectors) shall be provided on all slopes. On stems with exposed heights less than or equal to 5 feet, access shall be provided by a shelf at the top of the slopes. On stems with exposed heights greater than 5 feet, access may be by a shelf at the top of the slopes or ladder stops on the slope itself. The contract shall include details of the intersection of the shelf and the slope along the wingwalls.

5.10 SURFACE TREATMENTS

5.10.1 General

In general, abutments, piers and walls shall be faced with standard formed concrete. Surface treatments other than standard formed concrete should only be considered in the following situations:

- When the structure has been determined by the **CTDOT** to be architecturally or historically significant.
- If there is a desire expressed for special surface treatments during the public involvement process of the project. The basis for surface treatments should involve the character of the area in which the wall is to be built. The use of special surface treatments should be coordinated with the town or city administration.
- Where the structure is to be built on a designated State scenic highway.
- The structure is part of the Merritt Parkway. For these structures, every attempt should be made to replicate the appearance and structure type that was originally built.
- The treatment of the structure is part of a right-of-way settlement with a property owner. For instance, if a property has an existing stone wall that is to be removed and relocated, the owner may request that the replacement wall also have a stone surface.

If special surface treatments are desired for a particular structure, every attempt should be made to achieve architectural aesthetics by means of shape and form, not through surface treatments alone. Surface treatments should generally be used in conjunction with the shape of the structure.

5.10.2 Form Liners

When the use of surface treatments has been determined to be appropriate, the preferred method is the use of concrete form liners. Form liners offer a lower cost alternative to stone veneer. There is a wide variety of form liners available for different architectural treatments. Linear corrugated form liners should be avoided since it is difficult to hide joint lines and form tie holes. Form liners that replicate stone are preferred since the random nature of the surface makes it easy to hide form tie holes.

5.10.3 Simulated Stone Masonry

In more sensitive areas, where the look of real stone is required, the use of simulated stone masonry may be considered. Simulated stone masonry utilizes a flexible form liner system and color stains or dry-colorant admixtures to provide the aesthetic appeal of natural stone with the durability of reinforced concrete.

5.10.4 Stone Veneer

The use of stone veneer on concrete should only be considered in very sensitive areas where the increased cost can be justified. Stone veneer shall only be used with approval from the CTDOT.

5.11 REQUIREMENTS FOR ABUTMENTS

5.11.1 General

The abutments shall be designed, unless otherwise noted, in accordance with the **LRFD**.

Generally, abutments shall be constructed of reinforced concrete. Cast-in-place footings and stems shall be constructed in accordance with **BDM** [6].

5.11.2 Gravity and Counterfort Abutments

5.11.2.1 Steel Girder and Concrete Bulb Tee and Box Girder Bridges

Gravity, cantilever, and counterfort walls, with bridge seats, may be used for abutments.

Bridge seats shall be sloped with a minimum 2 inch draw from the front face of the backwall and closed at the ends. When determining bridge seat widths, consideration shall be given to superstructure jacking requirements as given in **BDM** [7.2.13] and the clear distance requirements between the end bearing diaphragms and the front face of the backwall as given in **BDM** [7.3.3.7]. On bridges constructed with box girders, the clear distance from the end of the box girder to the face of the backwall should be no less than two feet.

At the elevation of the bridge seat, the minimum dimension from the front face of the abutment stem to the centerline of the bearings shall be 1.25 feet. The minimum backwall thickness shall be 1.25 feet. Stem thicknesses may be less than the combined dimensions of the bridge seat and backwall.

5.11.2.2 Butted Deck Unit and Box Beam

Gravity, cantilever and counterfort walls, with bridge seats, may be used for abutments.

Bridge seats shall be sloped to match the grade of beams. Provisions should be provided on the contract plans to provide drainage at the low end of span.

At the elevation of the bridge seat, the minimum dimension from the front face of the abutment stem to the centerline of the bearings shall be 9 inches. The minimum backwall thickness shall be 1.25 feet. Stem thickness may be less than the combined dimensions of the bridge seat and backwall.

5.11.3 Integral Abutments

Integral abutments are defined as abutments that are cast integrally with the superstructure. Integral abutments should be considered on all bridges, and especially where pile supported foundations are required, since the use of integral abutments will greatly reduce the number of piles and simplify the abutment details.

All integral abutment bridges shall be designed with full width approach slabs in order to minimize surcharge loads and hydrostatic pressures. Integral abutments shall be designed with U-Type wingwalls.

5.11.3.1 Fully Integral Abutments

Fully integral abutments are defined as abutments that are integral from the superstructure through to the piles. In order to control the effects of the soil mass on the abutment, the maximum height of the cast-in-place abutment shall be 8 feet.

The piles shall be placed in a single line and typically are oriented such that the weak axis of the pile is parallel to the abutment face. For design purposes, the connection of the superstructure to the substructure shall be modeled as a pinned connection. The piles shall be designed for vertical forces only and adhere to the guidelines in **HEC-18** and **HEC-22**. The effects of thermal expansion, end rotation of the superstructure, and soil forces should be neglected.

5.11.3.2 Semi-Integral Abutments

Semi-integral abutments are defined as abutments that are integral from the superstructure through a portion of the abutment stem. Typically, a joint will be detailed in the abutment stem. In order to control the effects of the soil mass on the abutment, the maximum height of the integral portion of the cast-in-place abutment shall be 8 feet.

For design purposes, the connection of the superstructure to the substructure shall be modeled as a pinned connection. The lower portion of a semi-integral abutment shall be designed as a standard cantilever abutment with all vertical forces from the superstructure transmitted to lower portion of the abutment.

5.12 REQUIREMENTS FOR PIERS

5.12.1 General

The piers shall be designed, unless otherwise noted, in accordance with the **LRFD**. Generally, piers shall be constructed of reinforced concrete. While the design of steel pier caps is allowed, they are discouraged. For additional information, see **BDM** [7]. Piers may be made integral with the superstructure.

Footings, concrete pier stems, columns, and pier caps shall be constructed in accordance with **BDM** [6]. Post-tensioned concrete pier caps may require concrete with greater compressive strengths.

All reinforcement in piers shall conform to **BDM** [6]. The concrete cover over the reinforcement in pier footings, stems, columns, and pier caps shall be 3 inches.

Circular concrete columns are preferred over rectangular concrete columns. With circular columns, spiral reinforcement is preferred over ties.

Cantilever concrete pier caps shall be post tensioned in order to eliminate cracking. The design shall be based on zero tension in the top of the cap after all losses have occurred under all loads.

The top surfaces of concrete piers and concrete pier caps shall have a transverse slope of 1:10 (rise to run). The slope shall be in both directions from the centerline to the face of the pier with a minimum draw of 2 inches.

Drilling holes for anchor bolts will not be permitted in concrete pier caps for new structures. Anchor bolts installed before the concrete is placed shall be set and held accurately by a template. Anchor bolts to be set after the concrete is poured shall be set in forms that shall be placed before the concrete is poured. The designer shall indicate in the contract which method of setting anchor bolts is to be used.

For structures over waterways, the following criteria applies:

- Pier foundations on floodplains should be designed to the same elevation as pier foundations in the stream channel if there is likelihood that the stream channel will shift its location over the life of the bridge.
- Align piers with the direction of flood flows. Assess the hydraulic advantages of round piers, particularly where there are complex flow patterns during flood events.
- Streamline piers to decrease scour and minimize the potential for the buildup of ice and debris. Use ice and debris deflectors where appropriate.

5.12.2 Wall Piers

A wall pier consists of a solid wall that extends up from its foundation. Generally, wall piers or wall piers combined with open bents should be considered at water crossings. Wall piers offer minimal resistance to water and ice flows.

5.12.3 Open Column Bents

An open column bent consists of a pier cap beam and supporting columns in a frame-type structure. Open column bents should be considered for wide overpasses at low skewes.

Open column bents founded on rock shall generally be designed with isolated footings while open column bents founded on soil shall generally be designed with combined footings. When these piers are founded on piles, they may be designed with either isolated or combined footings.

5.12.4 Multiple Column Piers

A multiple column pier consists of an individual column supporting each beam or girder. Multiple column piers should be considered for wide overpasses at low skew angles.

5.12.5 Single Column Piers

Single column piers are simple, easy to construct, require minimum space, and provide open appearance to traffic. Single column piers may have a hammer head pier cap. Hammer head piers should be considered for overpasses at high skew angles with tight alignment constraints. This type of pier provides open appearance when supporting structures with long spans.

5.12.6 Protection from Adjacent Traffic

To limit damage to piers by vehicular traffic, crash walls shall be provided. The minimum height of the wall shall be 42 inches, and shall be placed a minimum of 6 inches from the face of the pier.

To limit damage to piers by railroad equipment, crash walls shall be provided in accordance with **AREMA**. Extensions to crash walls may be required to satisfy site conditions. The top surface of the crash wall shall have a transverse slope of 12:1.

5.13 REQUIREMENTS FOR WALLS

5.13.1 General

The following is a list of appropriate retaining wall types that may be considered:

1. Non-Proprietary: Precast and Cast-In-Place Reinforced Concrete
2. Proprietary: Prefabricated Modular Wall Systems
Mechanically Stabilized Earth Walls (precast concrete)
Mechanically Stabilized Earth Embankment Walls (dry-cast block)

A design is required for the non-proprietary walls only. The Contractor shall be responsible for the structural/internal design of the proprietary walls. For projects where proprietary retaining walls are included, the walls will be bid as a lump sum for each site. The designer shall clearly define the horizontal, vertical, and transverse pay limits in the contract.

The **CTDOT** maintains a list of approved proprietary retaining walls for each category listed above. No other proprietary retaining walls will be allowed.

5.13.2 Wall Selection Criteria

The designer shall select the appropriate retaining walls for each site. The designer may need to contact wall manufacturers to ensure that each wall will be suitable at each site, and fit within the available right-of-way. The following general criteria should be followed for the selection of appropriate retaining walls:

5.13.2.1 Walls < 8 Feet (Measured from Front Grade to Back Grade)

5.13.2.1.1 Embankment Walls (Rev. 12/19)

Embankment walls are defined as mechanically stabilized earth structures faced with dry cast concrete block that are less than 8 feet high and support an embankment. Embankment walls are typically used to support earth only, not roadways or where there is a potential for future underground utilities or drainage structures. The mechanical strength of the wall comes from soil reinforcements comprised of either geogrids or welded wire mesh.

Embankment walls are proprietary wall systems, and there are several approved manufacturers of these types of walls. It is not necessary to design a cast-in-place retaining wall as an alternate; however, the designer shall lay out the embankment wall in the contract with at least the following information:

- Retaining wall plan view with all required dimensions, contours, property lines, utilities, etc.
- Retaining wall elevation view showing top and bottom elevations, approximate step locations, existing and finished grade, etc. Where required, the designer shall also show the location of railings or fences required to be attached to the top of the wall.
- Typical sections (schematic) of the wall showing pay limits and minimum drainage requirements.
- Borings and soils information including the maximum factored bearing resistance.
- Temporary Sheet piling required for excavation.

5.13.2.1.2 Cast-in-Place Walls

For locations where embankment walls are not appropriate (in accordance with the criteria listed above), a cast-in-place wall should be designed and detailed.

At the discretion of the **CTDOT**, proprietary walls may also be allowed if the wall is very long resulting in a large overall area. The designer shall provide the same information for proprietary walls as required in **BDM** [5.13.2.2.1].

If the appearance of stone is desired, architectural form liners should be used. These liners are significantly less costly than stone veneer. If there are multiple walls on a project, the surface treatment shall be similar for each wall.

5.13.2.2 Walls > 8 Feet (Measured from Front Slope to Back Slope)

5.13.2.2.1 Walls < Than 5,000 ft² of Vertical Face Area (Measured to Bottom of Footing)

For this situation, a cast-in-place wall should be designed to be bid against the proprietary walls. The Contractor may be able to build the cast-in-place wall with his own forces at a lower cost. For these situations, the designer shall completely design and detail the cast-in-place wall. For the proprietary retaining wall, schematic typical cross sections combined with the cast-in-place details should be enough for the proprietary wall manufacturers to design their walls.

The designer shall provide a list of the specific wall types allowed for each site. For instance, the designer may limit the selection based on the available right of way at a site.

For mechanically stabilized earth walls with metallic soil reinforcements that are to be built in areas of potential stray currents within 200 feet of the structure (for example: an electrified railroad), a corrosion expert shall evaluate the potential need for corrosion control requirements.

If the wall is required to be designed for seismic loads, it shall be stated in the notes for the wall.

5.13.2.2.2 Walls > 5,000 ft² of Vertical Face Area (Rev. 12/19)

For this situation, proprietary retaining walls will most likely be more economical; therefore, a cast-in-place wall design should generally not be done except where site conditions or soil constraints may require a cast-in-place wall. The designer shall determine which proprietary retaining walls are appropriate for each site. The designer shall also lay out the proprietary retaining walls in the contract with at least the following information:

- A list of the specific walls allowed for each site. For instance, the designer may limit the selections based on the available right of way at a site.
- Retaining wall plan view with all required dimensions, offsets, contours, property lines, utilities, etc.

- Retaining wall elevation view showing top and bottom elevations, approximate footing step locations, existing and finished grade, etc. Where required, the designer shall also show the location of railings or fences, light standard and/or sign support anchorage locations, rigid metal conduit and junction boxes.
- Typical Sections (schematic) of the wall showing pay limits and minimum drainage requirements. Specific details are not required for each wall manufacturer, only for each wall type.
- All soils information normally used for the design of a cast-in-place wall shall be shown in the contract, including but not limited to borings and maximum factored bearing resistance.
- Temporary Sheet piling required for excavation.
- If the wall is required to be designed for seismic loads, it shall be stated in the notes for the wall.
- For mechanically stabilized earth walls with metallic soil reinforcements that are to be built in areas of potential stray currents within 200 feet of the structure (for example: an electrified railroad), a corrosion expert shall evaluate the potential need for corrosion control requirements.

5.13.2.2.3 Inverted Wall Systems (Rev. 12/19)

Inverted wall systems are modular block walls with a modified design methodology where smaller modular units are at the bottom of the wall and larger units at the top.

Due to the current sole source requirement, inverted wall systems can only be used where site conditions restrict the use of all other retaining wall systems. Inverted wall systems are well-suited for the specific scenario in which ground conditions restrict the use of temporary earth retaining systems (such as where ledge prohibits driven or drilled piles; adjacent structures may be damaged due to vibrations) and open excavation is restricted (e.g. – undermining of adjacent structures, utilities, etc.; Rights-of-Way constraints).

5.13.2.3 Architectural Treatments

If the appearance of stone is desired, architectural form liners should be used. These liners are significantly less costly than stone veneer. Several of the proprietary retaining walls can be built with form liners resembling stone. The designer should contact the approved wall manufacturers for specifics about available form liners. Every effort should be made to keep the surface treatment similar for all the wall types specified.

5.13.2.4 Large Anticipated Settlements and Liquefaction

If large settlements or liquefaction are anticipated that require a wall supported on piles, in general, proprietary retaining walls should not be used. Even though these walls can accommodate some settlement, the opening and closing of the joints would produce an undesirable appearance. For these situations, a cast-in-place wall should be designed supported on piles, or the proprietary retaining walls shall be detailed with pile supported full width footings.

5.13.2.5 Walls Supporting Roadways

If the wall supports a roadway where there is a possibility of future underground utilities and drainage structures, mechanically stabilized earth walls should not be used. This would not be the case for walls supporting limited access highways. If the utilities are extensive or deep, it may not be possible to use the modular wall options either.

5.13.2.6 Multiple Walls in Same Project

If there are several retaining walls within the same project, the designer may wish to require that all walls selected by the Contractor for the project be manufactured by the same wall supplier. This is especially true for walls that are close together.

5.13.2.7 Pre-Construction Procedures

The designer should contact the wall companies for tall walls or walls with unusual geometry to be sure that the proprietary walls will function at each site. This should be done during the preliminary design phase of the project.

Prior to construction advertising, the designer should inform in writing each proprietary wall company that they are listed as acceptable alternates in the contract. This will allow them to obtain the contract in order to accomplish preliminary design during advertising for the project. Part of this submission should include the anticipated advertising date.

5.13.3 Requirements for Cast-in-Place Non-Proprietary Walls

5.13.3.1 Flared Type Wingwalls and Retaining Walls

The stems of flared type wingwalls shall be 1.33 feet wide at the top, with the rear face battered. The minimum batter shall be 10:1.

5.13.3.2 U-Type Wingwalls with Sidewalks

The top of the wingwall section shall conform to the parapet width for the full length. If a batter is required, the rear face shall be vertical to approximately 12 inches below the sidewalk.

5.13.3.3 U-Type Wingwalls with Sloped Curb

The top of the wingwall section shall conform to the parapet width for the full length. If a batter is required, the rear face shall be vertical to approximately 12 inches below the bottom of subbase.

5.14 REQUIREMENTS FOR FOUNDATIONS

5.14.1 Structures over Waterways

Substructures for bridges over waterways shall be designed to safely support the structure subjected to the design scour. This policy is based upon the design guidelines contained within **HEC-18** wherein it states that “Bridges should be designed to withstand the effects of scour from a superflood with little risk of failing.”

5.14.1.1 Scour Evaluation Studies

All bridge scour evaluations shall be conducted with the procedures contained within the **Drainage Manual**.

The following categories of reports are available:

Detailed (Level II) Bridge Scour Evaluations and Re-evaluation Reports – These are comprehensive studies accomplished in conformance with the requirements of **HEC-18** and the **Drainage Manual**.

Comparative Scour Reports – These studies were developed using data obtained from Level II evaluations as a basis for determining the scour vulnerability of bridges having similar characteristics. Comparative evaluations are not as detailed as Level II reports, however they do provide NBIS ratings and the associated general scour classifications.

USGS Screening Reports - These studies, conducted by the U.S. Geological Survey, were undertaken to identify low risk bridges and to prioritize the remaining structures for further study. They are less detailed than either Level II Reports or Comparative Evaluations.

Based on the conclusions noted within these documents, all bridges over water have been classified into one of three general categories, Low Risk (NBIS Item 113 Rating of 8 or 9), Scour Susceptible (NBIS Item 113 Rating 4 or 5) or Scour Critical (NBIS Item 113 Rating of 3 or below). The NBIS Item 113 rating of 7 is reserved for bridge locations at which countermeasures have been installed to mitigate a previous scour problem. If the structure is a clear span bridge (no piers) and if the countermeasures have been designed in accordance with the procedures contained within HEC-23, the bridge may be considered “low risk.” When countermeasures are placed adjacent to piers to correct a previous scour condition, the bridge is classified as “scour susceptible.”

5.14.1.1.1 New Bridges over Waterways

Level II Scour Evaluations shall be performed for all new bridges over waterways unless one or more of the following conditions apply:

- The bridge has been designed to span the entire floodplain for the superflood (500 year recurrence interval) or the critical design event is less than the 500 year flood.
- The structure foundations will be set directly on sound bedrock.
- The abutment footings will be protected with riprap designed in accordance with the methods outlined in the latest version of “Bridge Scour and Stream Instability Countermeasures” (**HEC-23**) or successor documents. The use of riprap as the sole means of providing scour protection for new bridges is discouraged as noted below.

5.14.1.1.2 Reconstructed or Rehabilitated Bridges

Generally, scour evaluations shall be performed for all bridges that are to be reconstructed or rehabilitated where significant capital investment is involved and where the bridge has been classified as scour susceptible or scour critical. A significant capital investment correlates to the following improvement categories:

- Deck replacement
- Superstructure replacement or widening
- Modification or major repairs to substructure units

Scour evaluations shall not be required where structures to be reconstructed or rehabilitated have been classified as low risk under the **CTDOT**'s Bridge Scour Evaluation Program or for scour susceptible bridges which are not undergoing substructure modification and have had countermeasures installed following a Level II study.

Bridges which have been classified as scour susceptible or scour critical shall have hydrologic, hydraulic and scour evaluations performed which are sufficiently detailed to satisfy all applicable design and permitting requirements. If a detailed (Level II) scour evaluation has already been performed, the designer shall modify the results of this document as necessary to incorporate the “Modified Abutment Equations” contained within the **Drainage Manual**. All necessary scour countermeasures for scour susceptible or scour critical bridges shall be incorporated into the contract.

Maximum Design Foundation Pressure = 3.6 TSF (Extreme Event II)

5.14.3 Foundations on Rock

Generally, for cast-in-place construction, gravity-type or semi-gravity L-type sections shall be used for abutments, wingwalls and retaining walls founded on rock. There is no minimum embedment for footings placed on competent rock. Generally, structural underwater concrete is not permitted.

5.14.4 Driven Piles (Rev. 01/09)

Piles may be either end bearing or friction or a combination of the two. Piles end bearing on bedrock or dense hardpan typically are steel H-piles. Piles driven through a high compacted fill or into native soil containing numerous boulders and cobbles shall be steel H-piles. Generally, H-piles shall conform to the requirements of ASTM A709 Grade 50. Friction piles shall be used for most other cases. Generally, friction piles are precast concrete, cast-in-place concrete or prestressed concrete. Timber piles are not permitted.

Piles may be installed vertical or battered. The path of battered piles should be checked to insure the piles remain within the right of way and do not interfere with piles from adjacent and existing substructure units, nor conflict with temporary sheeting or cofferdams.

Pile foundations supporting abutments shall have a minimum of two rows of piles, unless the piles are incorporated into a fully integral abutment. Piles shall be anchored to and embedded in the footings a minimum of 12 inches.

Maximum pile spacing and maximum nominal resistance per pile should be utilized to minimize the number of piles. The lateral resistance of a pile pattern is the combination of the lateral component of the force acting on the battered piles and the lateral resistance of each pile, vertical and battered, in the pattern.

Test piles are typically required to establish pile order lengths and pile capacity for friction piles. If pile driving records and pile load test data are available for a site (e.g. a bridge widening where the same pile type is proposed), specifying the pile order length in the contract may be considered. Test piles with dynamic monitoring will still be required to establish the ultimate pile capacity. Static pile load tests may also be considered.

Pile order lengths for end bearing piles on bedrock should be provided in the contract when there is confidence in the subsurface profile. If a test pile(s) is being considered to establish order lengths for end bearing piles on bedrock, the benefit of the refined pile order length shall be weighed against the time required to obtain the production piles. Test piles with dynamic monitoring and/or static load tests may still be required to establish the ultimate pile capacity. The need for test piles is evaluated by the geotechnical engineer and should be included in the Geotechnical Report.

Readily available pile types should be used whenever possible; especially if the order length cannot be established until after test piles are driven. The location of test piles and load tests should be in areas that are readily accessible, and allow enough room for the Contractor to perform the work. A preconstruction test pile program may be considered on large projects where a benefit can be realized by establishing pile type(s) and pile capacity during the design phase.

If no test piles are specified for a given substructure, the estimated pile length shall be used as the pile order length. For these cases, the estimated pile length should be increased slightly to insure there is sufficient length.

The top of all footings should be a minimum of 12 inches below the finished grade. The bottom of all pile caps shall not be less than 4 feet below, measured normal to the finished grade.

For H-piles, pile point reinforcement and splices shall be prefabricated. The contract shall specify that the Contractor is required to submit pile point reinforcement and splice details to the Engineer for review and approval.

This following note shall be included on the contract drawings:

Prior to driving the piles, the Contractor shall submit to the Engineer for review and approval his method and sequence of pile driving.
--

The pile plan(s) included in the contract drawings shall show or note the following:

- A legend denoting vertical, battered and test piles.
- The number, location and length of test piles, if applicable.
- The location of load test pile(s), if applicable.
- The location of dynamic monitoring (pda) pile(s), if applicable.
- The number, location and estimated length for vertical and battered production piles. If no test pile is specified or if the estimated pile length is intended to be used as the order length, the following note shall be included:

The estimated pile length(s) is to be used as the pile order length.
--

- Material designation of piles, including pile point reinforcement and splices.
- The maximum design pile load for the controlling Strength and Service Limit States for each foundation section.

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Maximum Design Pile Load = 57 Tons (Strength I)
55 Tons (Service I)

If applicable, also show the maximum design pile load for the Extreme Event Limit State.

Maximum Design Pile Load = 67 Tons (Extreme Event II)

- The ultimate pile capacity for each foundation section, as defined as:
Ultimate Pile Capacity = (Factored Design Load)/ ϕ + Scour + Downdrag

Scour= The estimated skin friction resistance of the soil above the predicted scour depths.

Downdrag= The estimated side friction resistance of a compressible soil above the neutral point (determined when computing the downdrag load (DD) due to settlement).

Φ = The resistance factor based on the design load limit state, resistance determination method, and required field testing.

Example:

ULTIMATE PILE CAPACITY	
Abutment 1	XX tons
Pier No. X	XX tons
Abutment 2	XX tons

The Scour and Downdrag resistance along with Φ will be determined by the geotechnical engineer and included in the geotechnical report. The Contractor will use the Ultimate Pile Capacity to properly size pile driving equipment and load testing apparatus. The Engineer will use the Ultimate Pile Capacity to establish the required driving resistance and validate load test results.

5.14.5 Drilled Shafts

Vacant

5.15 EARTH RETAINING SYSTEMS AND COFFERDAMS *(Rev. 01/09)*

5.15.1 Highway Applications *(Rev. 01/09)*

The location and limits, both horizontal and vertical, of all temporary and permanent earth retaining system contract items shall be shown at each location.

5.15.1.1 Permanent Steel Sheet Piling *(Rev. 01/09)*

Permanent Steel Sheet Piling is defined as a required and permanent structural element integral to the design of the structure. Permanent Steel Sheet Piling is designed and engineered by the Designer. To avoid unnecessary proprietary specificity, permanent steel sheet piling should be specified and designated by AASHTO or ASTM material classification and minimum required section modulus.

5.15.1.2 Temporary Earth Retaining Systems *(Rev. 01/09)*

Temporary earth retaining system shall be any type of adequately braced temporary retaining wall which the Contractor elects to build to satisfy, and which does satisfy, the condition that existing facilities be properly retained during excavation or fill for the placement of substructure or other facilities. A Temporary Earth Retaining System shall be designated in the contract to be left in place only if its removal may be detrimental to the structure. The item "Earth Retaining System Left in Place" shall be used only for a Temporary Earth Retaining System designated by the Designer to be left in place. A Temporary Earth Retaining System requested by the Contractor to be left in place for his own convenience is not compensable for additional payment.

5.15.2 Railroad Applications *(Rev. 01/09)*

The location and limits, both horizontal and vertical, of all temporary and permanent earth support systems necessary for the construction of railroad structures must be shown in the contract. All contract items for temporary and/or permanent earth support systems for railroad structures and facilities must be submitted to the affected railroad for review during the standard project design submission phases. Contract plan details for temporary earth support in railroad applications must be specific in name and include a railroad parenthetical in the contract item name. Typical items for such use are "Temporary Sheet Piling (Railroad)" and "Soldier Pile and Lagging (Railroad)". The Designer should select the most appropriate temporary retaining system type in consideration of existing soil conditions and construction access limitations.

5.15.2.1 Permanent Steel Sheet Piling *(Rev. 01/09)*

Permanent Steel Sheet Piling adjacent to railroad tracks shall be designed for each specific location and shown in the contract. It should be specified and designated as noted in **BDM** [5.15.2] above.

5.15.2.2 Temporary Earth Support Systems *(Rev. 01/09)*

Through communication with the affected railroad company during a project's scope development, a determination will be made whether or not a complete design for a temporary earth support system is required. When the temporary earth support system is fully designed by the Designer, the contract special provision for the subject item should allow for the Contractor to submit an alternate design.

The Designer shall evaluate the global stability of the railroad embankment for the temporary (and permanent) condition. In cases where the stability of the embankment may be compromised, the Designer shall either provide a complete design or include the necessary constraints for a Contractor to properly design the earth support system.

Working drawings and design calculations prepared by the Contractor shall be submitted to the **CTDOT** and affected railroad company for review.

Items, such as "Sheet Piling left in Place (Railroad)" and "Soldier Pile and Lagging Left in Place (Railroad)" shall be designated in the contract only if their removal may be detrimental to the structure, as determined by the Designer in concert with the affected railroad company. Any system requested to be left in place by the Contractor for his convenience is not compensable.

5.15.3 Water-Handling-Cofferdams and Temporary Water Redirection *(Rev. 01/09)*

Water-Handling-Cofferdams and various methods to temporarily redirect water from the site are used so that construction can take place in the dry. Various methods and items may be used to achieve this end depending on the nature of the site, the nature of the construction, and the amount of water encountered. Because of the need to secure environmental permits, considerable detail of the dewatering plan intended may be required in the contract.

5.15.3.1 Structure Excavation (Complete) *(Rev. 07/04)*

The items "Structure Excavation-Earth (Complete)" or "Structure Excavation-Rock (Complete)" are generally used where water intrusion into the excavation results from groundwater seepage or very minor stream or drainage flow. There is no additional payment for dewatering or temporarily diverting water since the work required to construct in the dry is considered to be of such a minor nature that it can be considered to be incidental to the excavation items. Any cofferdams, temporary redirection, pumping, or any other dewatering methodology is included in the cost of the work. Generally, since the impact on water resources is so small, very little detailing is required in the contract.

5.15.3.2 Handling Water *(Rev. 07/04)*

If a structure cannot be constructed in the dry, a cofferdam is needed. The item "Handling Water" is generally used where a temporary redirection of a watercourse is required and is

generally used for construction of culverts or retaining walls adjacent to the watercourse. This lump sum item includes any temporary water handling structures such as barriers, temporary pipes, or drainage channels, necessary to complete the work. Also included is any excavation required to accomplish the temporary redirection of surface water.

Any required excavation for the permanent construction will be paid for under the items “Structure Excavation-Earth (Complete).” “Structure Excavation-Rock (Complete)” or appropriate excavation items. A conceptual scheme showing all temporary water handling structures such as barriers, temporary pipes, and drainage channels, and a conceptual scheme for staging of construction for water handling must be shown in the contract and will usually be included in permit applications. The hydraulic design of the aforementioned temporary facilities is based on the watercourse hydrology and information contained in the **Drainage Manual** [6.15]. A temporary design water surface elevation associated with the proposed temporary hydraulic facility should be shown in the contract and the permit plates.

The contractor will be required to submit working drawings to detail the proposal shown in the contract. If the contractor’s working drawings differ from the proposal shown on the contract to the extent that a revision to the permit is required, the contractor will be required to prepare and apply for any revisions required to the permit.

5.15.3.3 Cofferdam and Dewatering (Rev. 07/04)

The item “Cofferdam and Dewatering” is generally used where substructure elements are located partly or wholly in the streambed and where the bottom of footing is below water level, or on foundation work where considerable flow or concentration of water is present that cannot be conveniently temporarily redirected from the site. The extent of work involved in placing and dewatering the cofferdam is such that it is more than a minor part of the excavation items and is not considered incidental to those items. This item should be used in conjunction with the items “Structure Excavation-Earth (Excluding Cofferdam and Dewatering)” and “Structure Excavation-Rock (Excluding Cofferdam and Dewatering)”.

A cofferdam forms an enclosure that may be completely dewatered to allow work in the dry. It may consist of steel sheet piling or any other material the contractor elects to use to satisfy this requirement. Some sides of the cofferdam may be formed by the existing stream bank or by existing structures such as abutments or retaining walls. However, any existing structures intended to be used must extend below the anticipated bottom of excavation and must be resistant to intrusion of significant amounts of water from below the footing.

Cofferdams that encroach into water channels must be hydraulically analyzed based on the watercourse hydrology and information contained in the **Drainage Manual** [6.15]. A temporary design water surface elevation associated with the proposed temporary hydraulic facility should be shown in the contract and the permit plates.

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The horizontal and vertical limits of the cofferdam must be shown in the contract. Cofferdams are designed and detailed by the Contractor and submitted to the Engineer for review.