Bridge Inspection (Part 1): Abutments and Wingwalls (BIRM)

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Topic 10.1 Abutments and Wingwalls

10.1.1 Introduction

The substructure is the component of a bridge that includes all elements supporting the superstructure. Its purpose is to transfer the loads from the superstructure to the foundation soil or rock.

An abutment is a substructure unit located at the end of a bridge. Its function is to provide end support for the bridge superstructure and to retain the approach roadway embankment. Wingwalls are also located at the ends of a bridge. Their function is only to retain the approach roadway embankment and not to provide end support for the bridge.

Wingwalls are considered part of the substructure component only if they are integral with the abutment. When there is an expansion joint or construction joint between the abutment and the wingwall, that wingwall is defined as an independent wingwall, i.e. a retaining wall, and not considered in the condition evaluation of the abutment/substructure component.

10.1.2 Design Characteristics of Abutments

Abutment Types

Abutments are classified according to their locations with respect to the approach roadway embankment. The most common abutment types are presented in Figure 10.1.1 and include:

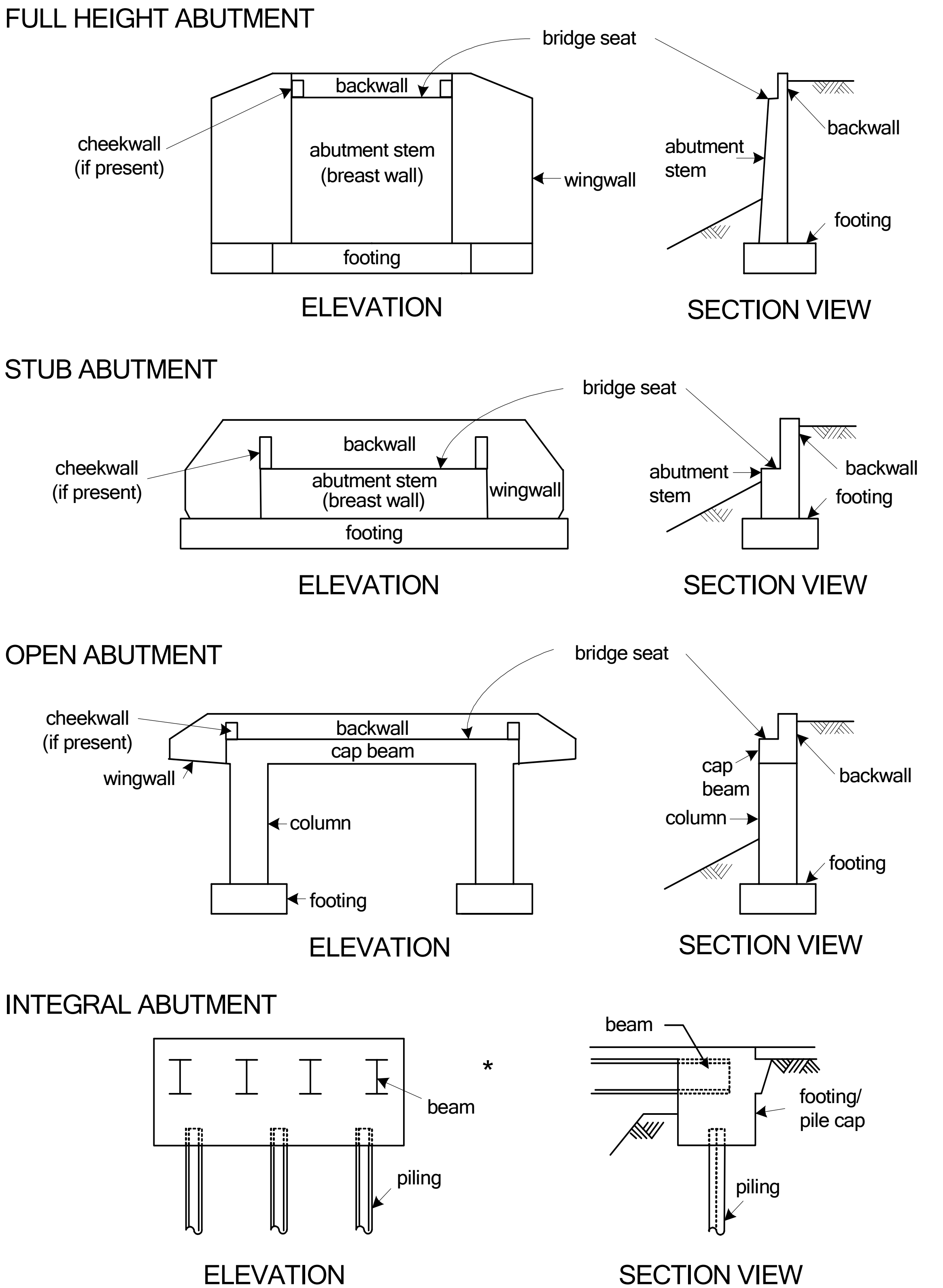
- Full height or closed type
    - Gravity
    - Counterfort
    - Cantilever
    - Curtain wall/Pedestal
    - Timber bent
    - Crib
- Stub, semi-stub, or shelf type
- Open or spill-through type
- Integral type

Foundations consist of either spread footings or deep foundations. See page 10.1.16 for a detailed description of abutment foundation types.

Less common abutments used to support highway bridges are shown in Figure 10.1.2 and include:

- Mechanically Stabilized Earth (MSE)
- Geosynthetic Reinforced Soil (GRS)

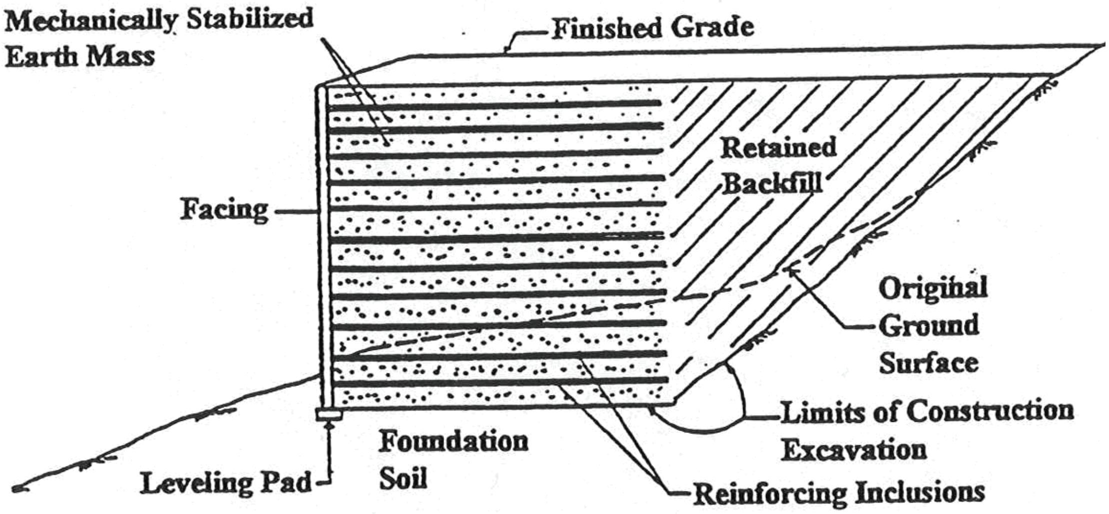
Detailed descriptions of abutment elements are provided on page 10.1.14.



* Some states weld beam and piles prior to concrete placement

Figure 10.1.1 Schematic of Common Abutment Types

MECHANICALLY STABILIZED EARTH (MSE)



GEOSYNTHETIC REINFORCED SOIL (GRS)

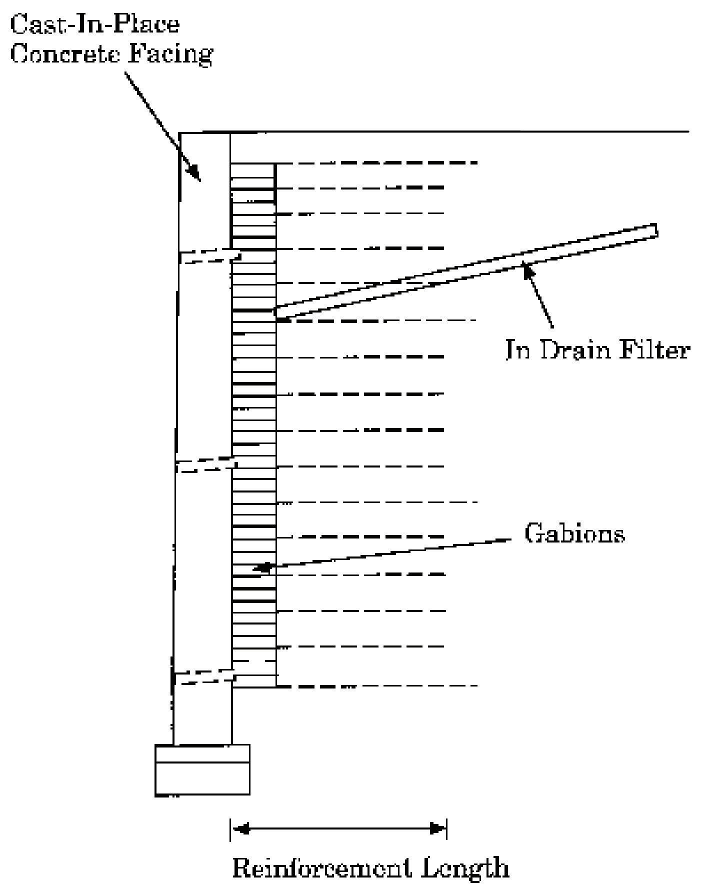


Figure 10.1.2 Section View of Less Common Abutment Types

Figure 10.1.3 Full Height Abutment

Figure 10.1.4 Stub Abutment

Full Height Abutments and Stub Abutments

Full height abutments are used when shorter spans are desired or if there are Right-of-Way or terrain issues. This reduces the initial superstructure costs. Stub abutments may be used when it is desirable to keep the abutments away from the underlying roadway or waterway. Longer spans are required when stub abutments are used. Using stub abutments reduces the cost of the substructure but increases the cost of the superstructure.

Figure 10.1.5 Open Abutment

Open Abutments

Open, or spill-through, abutments are similar in construction to multi-column piers. Instead of being retained by a solid wall, the approach roadway embankment extends on a slope below the bridge seat and between ("through") the supporting columns. Only the topmost few feet of the embankment are actually retained by the abutment cap.

The advantages of the open abutment are lower cost since most of the horizontal load is eliminated, so the massive construction and heavy reinforcement usually associated with the abutment stem is not needed. This substructure type has the ability to convert the abutment to a pier if additional spans are added in the future.

Open abutment disadvantages include a tendency for the fill to settle around the columns since good compaction is difficult to achieve in the confined spaces. Excessive erosion or scour may also occur in the fore slope. Rock fill is sometimes used to counter these problems.

This abutment type is not suitable adjacent to streams due to susceptibility to scour.

Integral Abutments

Most bridges have superstructures that are independent of the substructure to accommodate bridge length changes due to thermal effects. Expansion devices such as deck joints and expansion bearings allow for thermal movements but deteriorate quickly and create a wide range of maintenance needs for the bridge. In extreme cases, lack of movement due to failed expansion devices can lead to undesirable stresses in the bridge. Integral abutments supported by a single row of piles are becoming more popular and provide a solution to these problems.

In this design, the superstructure and substructure are integral and act as one unit without an expansion joint (see Figure 10.1.6). Relative movement of the abutment with respect to the backfill allows the structure to adjust to thermal expansions and contractions. Pavement joints at the ends of approach slabs are provided to accommodate the relative movement between the bridge and the approach roadway pavement.

The advantage of the integral abutment is that it lacks bearing devices and joints to repair, or replace, or maintain. There are two disadvantages of integral abutments: settlement of the roadway approach due to undercompaction of backfill and cracking of the abutment concrete due to movement restriction caused by overcompaction of backfill.

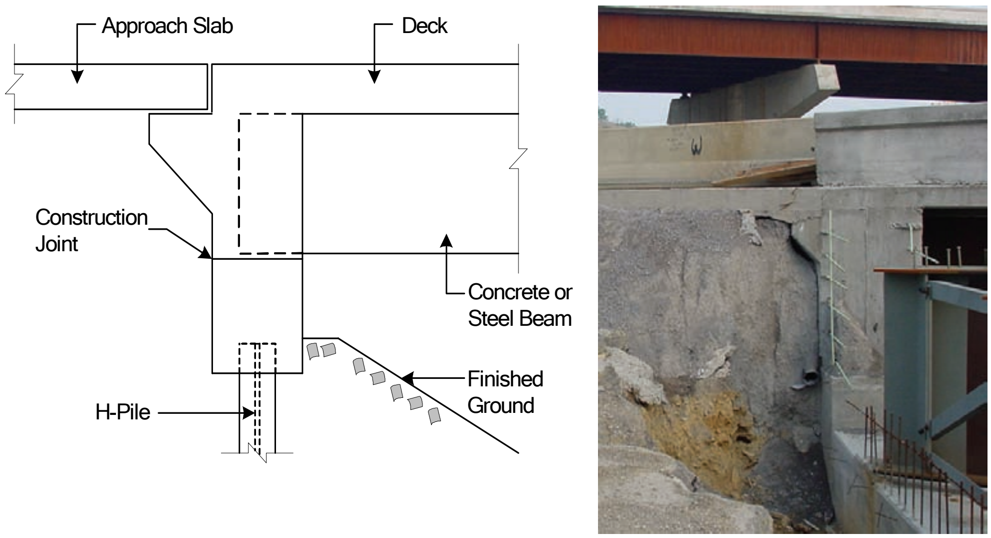


Figure 10.1.6 Integral Abutment

Figure 10.1.7 Integral Abutment

Less Common Abutment Types and Abutment Elements

Mechanically Stabilized Earth Abutments

Mechanically Stabilized Earth (MSE) Support Abutment typically consists of precast concrete panels, metallic soil reinforcing strips (flat strips or welded bar grids), and backfill to support the superstructure and support the roadway approach roadway embankment (see Figure 10.1.8). "Reinforced Earth" and "Retained Earth" are trademarked names given to these systems by suppliers of the components. Two MSE Abutment design concepts have been used. The first utilizes an MSE wall supporting a slab, or coping, on which the bridge bearings rest. Vertical loads are transmitted through the reinforced fill. The second concept utilizes piles or columns to support a stub abutment at the top of the reinforced fill. The piles provide vertical support for the bridge. The MSE provides lateral support for the approach roadway embankment.

Precast concrete panels are erected first, followed by the placement and compaction of a layer of backfill. The layers of backfill are sometimes referred to as "lifts." Soil reinforcement is then placed and bolted into the panels and covered with more backfill (see Figure 10.1.9). This process, which allows the wall to remain stable during construction, is repeated until the designed height is attained.

Advantages of this substructure are its internal stability and its ability to counteract shear forces, especially during earthquakes. It is generally lower in cost and has favorable esthetics when compared to a reinforced concrete full height abutment. Disadvantages include difficulty in repairing failed soil reinforcement and limited site applications. Another disadvantage is the possible settlement of an MSE wall that directly supports the superstructure (i.e. no stub abutment with piles).

Figure 10.1.8 Mechanically Stabilized Earth Abutment (Note Precast Concrete Panels)

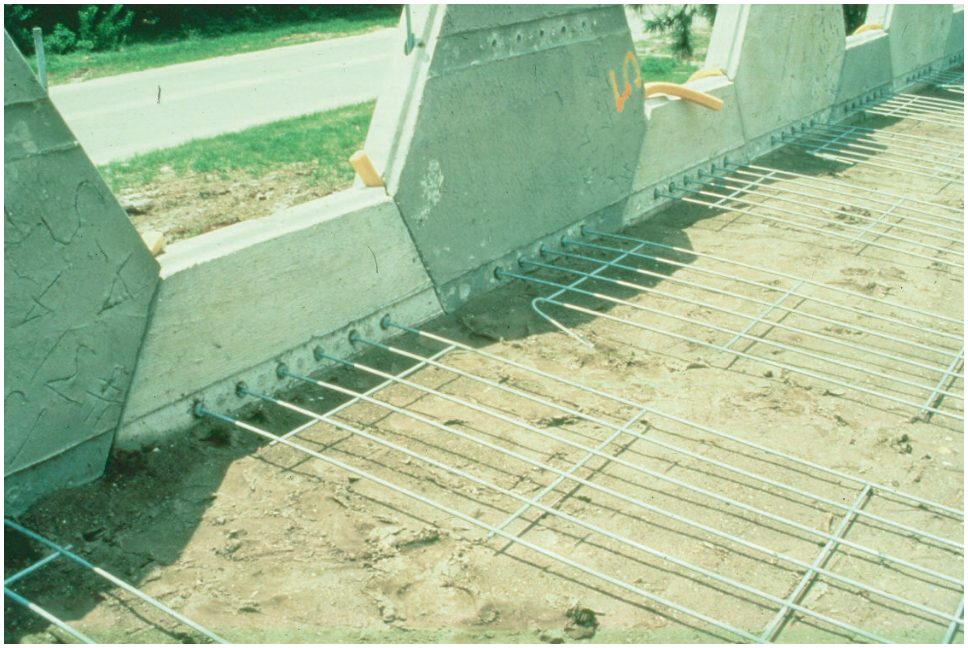


Figure 10.1.9 Mechanically Stabilized Earth Wall Under Construction

Geosynthetic Reinforced Soil Abutments

Another less common, fairly new type of abutment is the geosynthetic reinforced soil (GRS) abutment, developed by the Federal Highway Administration. GRS abutments are basically constructed on a level surface starting with a base structure of common, but high quality, cinder blocks. Fill is then placed and compacted with a sheet of geosynthetic reinforcement, which can be a series of polymer sheets or grids. These materials are layered until the designed height is attained. GRS abutments, which are internally supported, use friction to hold the blocks together and obtain their strength through proper spacing of the layers of reinforcement. Advantages of GRS abutments are their simplicity to construct, their durability, and their aesthetic appearance. GRS technology works well with simple overpasses; however, they are not ideal where severe flooding could occur (see Figures 10.1.10 and 10.1.11).

Figure 10.1.10 GRS Bridge Abutment Developed at the Turner-Fairbank Highway Research Center

The stabilized earth concepts, using metallic or geosynthetic reinforcement, are more commonly used as retaining walls or wing walls than as abutments. See Report No. FHWA-SA-96-071 (Demo 82 Manual) for a detailed description of these systems.

Figure 10.1.11 View of the Founders/Meadows Bridge Supported by GRS Abutments

Primary Materials

The primary materials used in abutment construction are plain cement concrete, reinforced concrete, stone masonry, steel (although not very common), timber, or a combination of these materials.

Figure 10.1.12 Plain Unreinforced Concrete Gravity Abutment

Figure 10.1.13 Reinforced Concrete Cantilever Abutment

Figure 10.1.14 Stone Masonry Gravity Abutment

Figure 10.1.15 Combination: Timber Pile Bent Abutment with Reinforced Concrete Cap

Figure 10.1.16 Steel Abutment

Primary and Secondary Reinforcement

The pattern of primary steel reinforcement used in concrete abutments depends on the abutment type (see Figure 10.1.17). In a cantilever abutment, primary tension reinforcement include: vertical bars in the rear face of the stem and backwall, horizontal bars in the bottom of the footing (toe steel), and horizontal bars in the top of the footing (heel steel). In a concrete open or spill-through abutment, the primary reinforcement consists of both tension and shear steel reinforcement. Tension steel reinforcement generally consists of vertical bars in the rear face of the backwall and cap beam, horizontal bars in the bottom face of the cap beam, vertical bars in the columns and horizontal bars in the bottom of the footing. Stirrups are used to resist shear in the cap beam. The column spirals or ties are generally considered to be secondary reinforcement to reduce the un-braced length of the vertical bars in the column. The spirals or ties may be considered primary reinforcement in seismic zones. All other bars would be temperature and shrinkage reinforcement, which is secondary reinforcement.

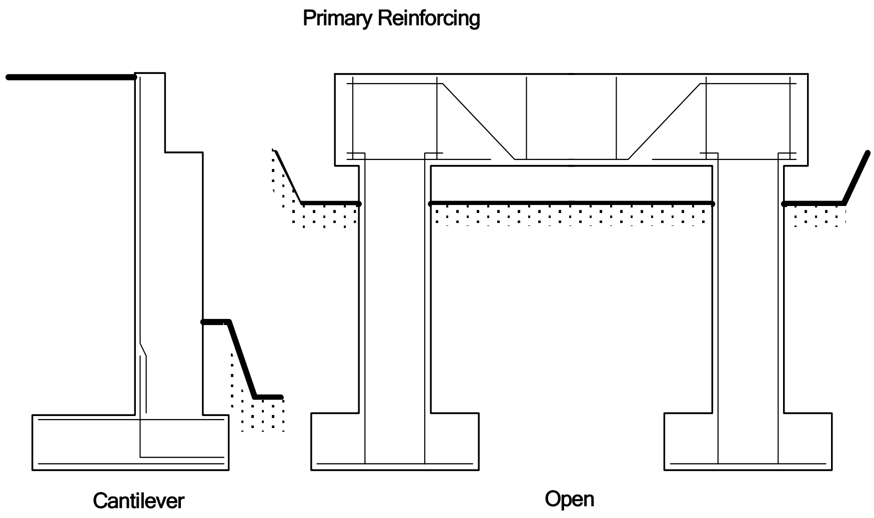


Figure 10.1.17 Primary Reinforcement in Concrete Abutments

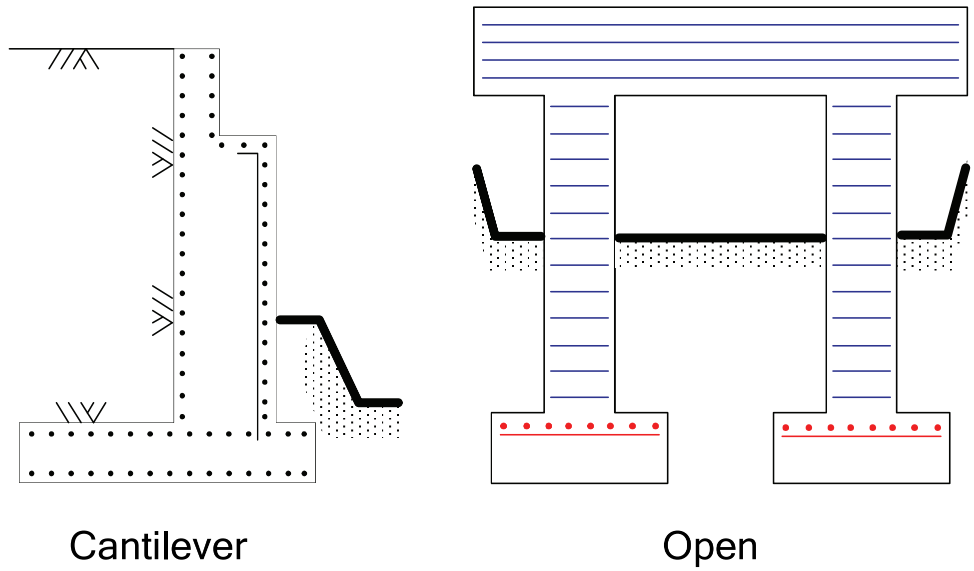


Figure 10.1.18 Secondary Reinforcement in Concrete Abutments

Abutment Elements

Common abutment elements include:

- Bridge seat
- Backwall
- Footing/Pile cap
- Cheek wall
- Abutment stem (breast wall)
- Tie backs
- Soil reinforcing strips
- Precast panels
- Deep foundations
- Geotextiles

The basic abutment elements are shown in Figure 10.1.1, Figure 10.1.2 and described below.

The bridge seat provides a bearing area that supports the bridge superstructure. The backwall retains the approach roadway subbase and keeps it from sliding onto the bridge seat. It also provides support for the approach slab and for the expansion joint, if one is present. The cheek wall is mostly cosmetic but also protects the end bearings from the elements, (see Figure 10.1.19). A cheek wall is not always present.

The abutment stem or breast wall supports the bridge seat and retains the soil behind the abutment. The foundation either spread footing or deep foundation (piles, drilled shafts, etc.), transmits the weight of the abutment, the soil backfill loads, and the bridge reactions to the supporting soil or rock. It also provides stability against overturning and sliding forces. The portion of the footing in front of the wall is called the toe, and the portion behind the wall, under the approach embankment, is called the heel.

Mechanically stabilized earth (MSE) walls consist of a reinforced soil mass and a concrete facing which is vertical or near vertical. The facing is often precast panels which are used to hold the soil in position at the face of the wall. The reinforced soil mass consists of select granular backfill. The tensile reinforcements and their connections may be proprietary, and may employ either metallic (i.e., strip- or grid-type) or polymeric (i.e., sheet-, strip-, or grid-type) reinforcement. The soil reinforcing strips hold the wall facing panels in position and provide reinforcement for the soil. Geotextiles are used to cover the joint between the panels. Geotextiles are placed behind the precast panels to keep the soil from being eroded through the joints and allow excess water to flow out. Tie backs are steel bars or strands grouted into the soil or rock behind the abutment stem. Tie backs, if present, are used when lateral earth forces cannot be resisted by the footing alone.

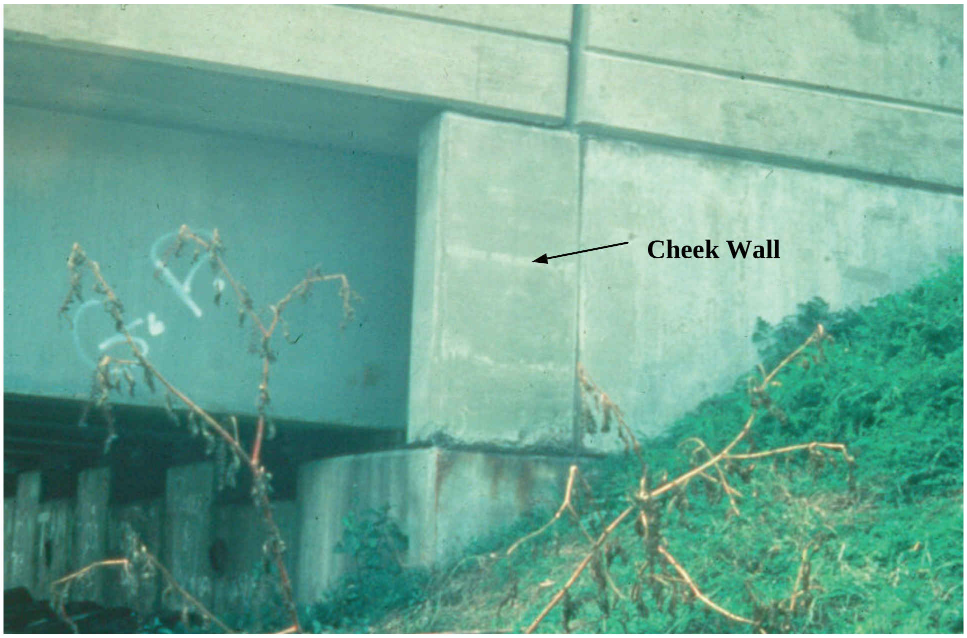


Figure 10.1.19 Cheek Wall

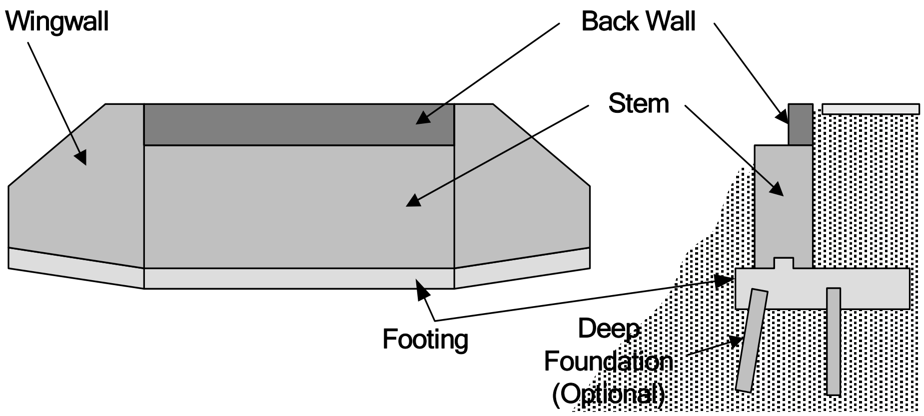


Figure 10.1.20 Spread Footing/Deep Foundations

Foundation Types

Foundations are critical to the stability of the bridge since the foundation ultimately supports the entire structure. The two basic types of bridge foundations shown in Figure 10.1.20 are:

- Spread footings
- Deep foundations

A spread footing is used when the bedrock layers are close to the ground surface or when the soil is capable of supporting the bridge. A spread footing is typically a rectangular reinforced concrete slab. This type of foundation “spreads out” or distributes the loads from the bridge to the underlying rock or soil. While a spread footing is usually buried, it is generally covered with a minimal amount of soil. In cold regions, the bottom of a spread footing will be placed below the recognized maximum frost line depth for that area.

A deep foundation is used when the soil is not suited for supporting the bridge. A pile is a long, slender support which is typically driven into the ground but can be placed in predrilled holes. Piles can be partially exposed and are made of steel, concrete (cast-in-place or precast), or timber. Various numbers and configurations of piles can be used to support a bridge foundation. This type of foundation transfers load to sound material well below the surface or, in the case of friction piles, to the surrounding soil.

“Caisson”, “drilled shafts”, or “bored pile” is another type of deep foundation typically used when the soil stratum is typically less than 3 meters (10 feet) from the footing bottom to bedrock. Holes are drilled through the soil and filled with reinforced concrete. Temporary or permanent steel casing is utilized during the construction process to support and retain the sides of a borehole. Temporary steel casing is removed after the concrete is placed and is capable of withstanding the surrounding pressures. The minimum diameter used for bridge substructure construction is normally 0.75 meters (30"). Caissons, drilled shafts or bored piles may be extended beyond 3 meters (10 feet) if economically feasible or if there are voids such as caverns or mines within the bedrock under the bridge.

Figure 10.1.21 Stub Abutment on Piles with Piles Exposed