Bridge Inspection (Part 2): Abutments and Wingwalls (BIRM)

Course No: S02-007

Credit: 2 PDH

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10.1.3 Inspection Procedures and Locations for Abutments

Inspection procedures for abutments are similar to superstructures, particularly when it involves material deterioration. See Topics 2.1 and 13.1 (Timber), Topics 2.2 and 13.2 (Concrete), 2.3 and 13.3 (Steel), or Topic 2.4 (Stone Masonry) for specific material defects and inspection procedures. However, because stability is a paramount concern, checking for various forms of movement is required during the inspection of abutments.

The locations for inspection are not particularly specific, but can be related to common abutment problems.

The most common problems observed during the inspection of abutments are:

- Vertical movement
- Lateral movement
- Rotational movement
- Material defects
- Scour and undermining of the foundation
- Drainage system malfunction
- Areas subjected to high stresses
- Areas exposed to traffic
- Fatigue prone details and fracture critical members

Vertical Movement

Vertical movement can occur in the form of uniform settlement or differential settlement. A uniform settlement of all bridge substructure units, including abutments and piers/bents, will have little effect on the structure. Uniform settlements of 0.3 m (1 foot) have been detected on small bridges with no signs of distress.

Differential settlement can produce serious distress in a bridge. Differential settlement may occur between different substructure units, causing damage of varying magnitude depending on span length and bridge type (see Figure 10.1.22). It may also occur under a single substructure unit (see Figure 10.1.23). This may cause an opening of the expansion joint between the abutment and wingwall, or it may cause cracking or tipping of the abutment, pier, or wall.

The most common causes of vertical movement are soil bearing failure, consolidation of soil, scour, undermining and subsidence from mining or solution cavities.

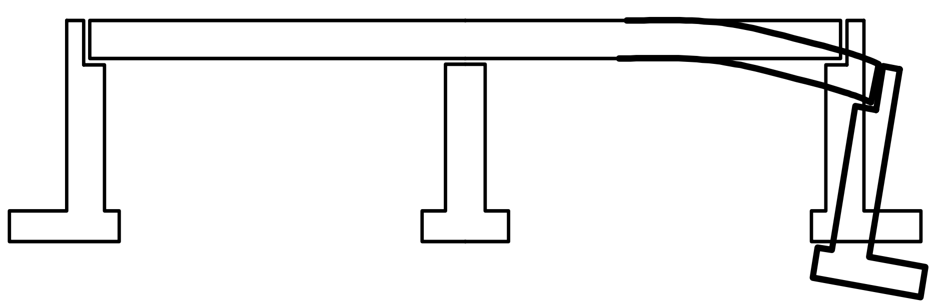

Figure 10.1.22 Differential Settlement Between Different Substructure Units

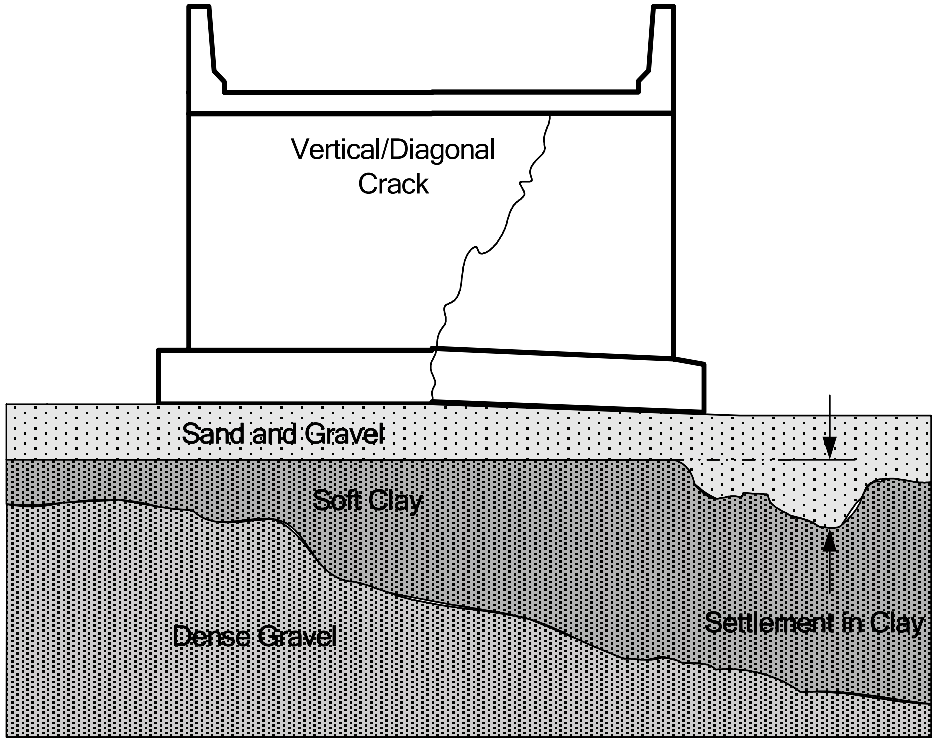

Figure 10.1.23 Differential Settlement Under an Abutment

Inspection for vertical movement, or settlement, should include:

- Inspect the joint opening between the end of the approach slab and the deck. In some cases, pavement expansion or approach fill expansion could conceivably cause vertical movement in the approach slab.
- Investigate existing and new cracks for signs of settlement (see Figure 10.1.24).
- Examine the superstructure alignment for evidence of settlement (particularly the bridge railing and deck joints).
- Check for scour and undermining around the abutment footing or foundation.
- Inspect the joint that separates the wingwall and abutment for proper alignment.

Figure 10.1.24 Crack in Abutment due to Settlement

Lateral Movement

Earth retaining structures, such as abutments and retaining walls, are susceptible to lateral movements, or sliding (see Figure 10.1.25). Lateral movement occurs when the horizontal earth pressure acting on the wall exceeds the friction forces that hold the structure in place.

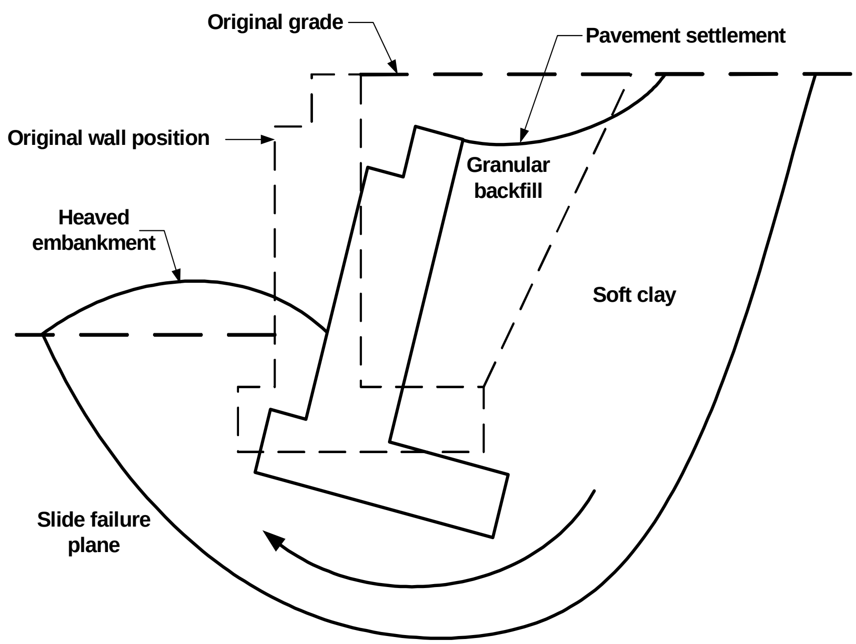

Figure 10.1.25 Lateral Movement of an Abutment due to Slope Failure

The most common causes of lateral movement are slope failure, seepage, changes in soil characteristics (e.g., frost action and ice), and time consolidation of the original soil.

Inspection for lateral movement, or sliding, should include:

- Inspect the general alignment of the abutment.
- Check the bearings for evidence of lateral displacement (see Figure 10.1.26).
- Examine the opening in the construction joint between the wingwall and the abutment.
- Investigate the joint opening between the deck and the approach slab (see Figure 10.1.27).
- Check the approach roadway for settlement.
- Check the distance between the end of the superstructure and the backwall.
- Examine for clogged drains (approach roadway, weep holes, and substructure drainage).
- Inspect for erosion, scour or undermining of the embankment material in front of the abutment (see Figure 10.1.28).

Figure 10.1.26 Excessive Rocker Bearing Displacement Indicating Possible Lateral Displacement of Abutment

Figure 10.1.27 Depressed Approach Slab due to Rotating Abutment

Figure 10.1.28 Erosion at Abutment Exposing Footing

Rotational Movement

Rotational movement, or tipping, of substructure units is generally the result of unsymmetrical settlements and / or lateral movements due to horizontal earth pressure (see Figure 10.1.29). Abutments and walls are subject to this type of movement.

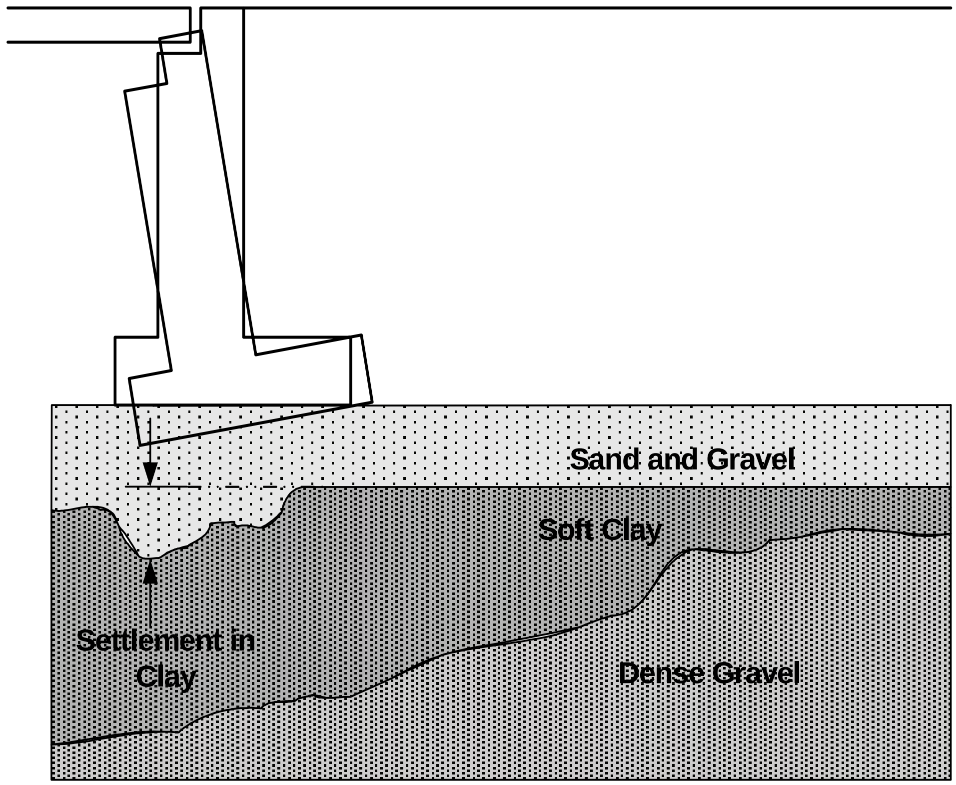

Figure 10.1.29 Rotational Movement of an Abutment

The most common causes of rotational movement are undermining, scour, saturation of backfill, soil bearing failure, erosion of backfill along the sides of the abutment, and improper design.

Inspection for rotational movement, or tipping, should include:

- Check the vertical alignment of the abutment using a plumb bob or level; keep in mind that some abutments are constructed with a battered or sloped front face (see Figures 10.1.30 and 10.1.31).
- Examine the clearance between the beams and the backwall.
- Inspect for clogged drains or weep holes.
- Investigate for unusual cracks or spalls.
- Check for scour or undermining around the abutment footing. See Topic 11.2 for a detailed description of scour and undermining. See Topic 11.3 for a detailed description of underwater inspection.

Figure 10.1.30 Rotational Movement at Abutment

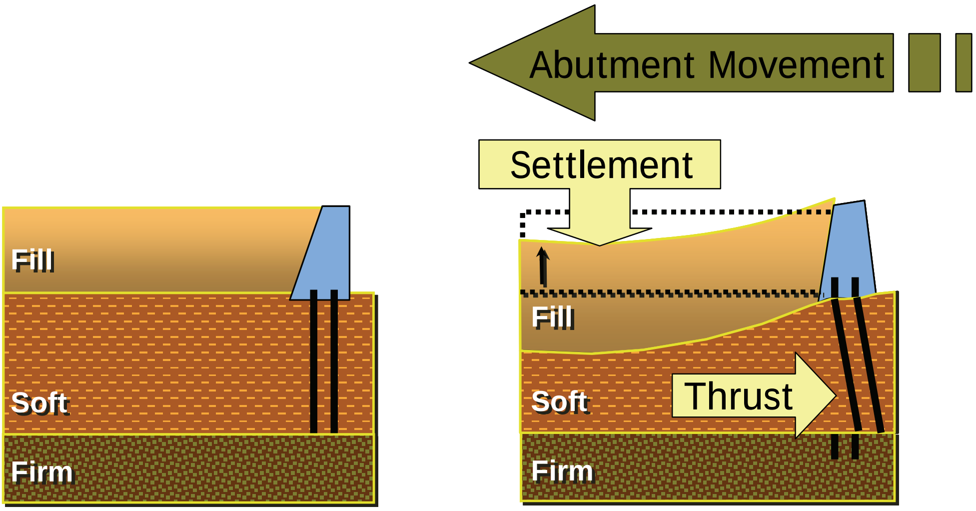

Figure 10.1.31 Rotational Movement due to "Lateral Squeeze" of Embankment Material

Material Defects

A common problem observed during the inspection of abutments is the presence of construction material defects. Refer to Topics 2.1 – 2.4 for a more detailed description of the types and causes of deterioration observed in timber, concrete, steel and stone masonry.

Concrete and Stone Masonry

Inspection for concrete and stone masonry material defects in abutments should include:

- Examine the bearing seats for cracking and spalling, particularly near the edges; this is particularly critical where concrete beams bear directly on the abutment seat (see Figure 10.1.32).
- Inspect for the presence of debris and standing water on the bearing seats.
- Investigate for deteriorated concrete in areas that are exposed to roadway drainage, particularly below the joint between the backwall and the deck (see Figure 10.1.33).
- Check the backwall for cracking and possible movement.
- Examine the construction joint between the backwall and the abutment stem.
- Inspect stone masonry for mortar cracks or loss of mortar in the joints (see Figure 10.1.34).
- Examine stone masonry for vegetation, water seepage through cracks, loose or missing stones, weathering, split, spalled, loose or missing blocks.

Several advanced techniques are available for concrete inspection. Nondestructive and other methods are described in Topics 13.2.2 and 13.2.3.

Figure 10.1.32 Cracking in Bearing Seat of Concrete and Stone Abutment

Figure 10.1.33 Deteriorated Concrete in Abutment Backwall

Figure 10.1.34 Deteriorated Stone Masonry Abutment

Steel

Although a steel abutment is uncommon (see Figure 10.1.35), the following items should be inspected if one is encountered:

- Examine bearing seat area for buildup of dirt and debris.
- After cleaning, check bearing seat area for corrosion and section loss.
- Inspect cap beam, piles, and any other steel elements for corrosion, cracking, and section loss.
- Investigate piles closely at the ground line.
- Check for scour and erosion around the piles.
- Examine all fasteners and connections for condition and tightness.

Several advanced techniques are available for steel inspection. Nondestructive and other methods are described in Topics 13.3.2 and 13.3.3.

Figure 10.1.35 Steel Abutment

Timber

Inspection for timber defects in abutments should include:

- Examine bearing seat for accumulated dirt and debris and prolonged exposure to moisture.
- Inspect for decay, insect damage, and crushing of the cap beam.
- Investigate for local failures in lagging or piles due to lateral movement (see Figure 10.1.36).
- Check crib timbers, timber lagging, and piles for splits, cracks, decay, insect damage, fire damage, and chemical attack (see Figure 10.1.37).
- Inspect for scour around the piles (see Figure 10.1.38).
- Examine piles very closely for decay at or near the ground line or

waterline.

- Investigate splices and connections for tightness and for loose bolts.
- In marine environments, examine piles for the presence of marine borers and caddis flies.

Several advanced techniques are available for timber inspection. Nondestructive and other methods are described in Topics 13.1.2 and 13.1.3.

Figure 10.1.36 Local Failure in Timber Pile due to Lateral Movement of Abutment

Figure 10.1.37 Decay in Lagging of Timber Crib Abutment

Figure 10.1.38 Decayed Lagging and Scour at a Timber Pile Bent Abutment

Scour and Undermining

Scour is the removal of material from a streambed as a result of the erosive action of running water (see Figure 10.1.39). Scour can cause undermining or the removal of supporting foundation material from beneath the abutments when streams or rivers flow adjacent to them. Refer to Topic 11.2 for a more detailed description of scour and undermining.

Figure 10.1.39 Abutment with Undermining due to Scour

Inspection for scour should include probing around the abutment footing for signs of undermining (see Figure 10.1.40). Sometimes silt loosely fills in a scour hole and offers no protection or bearing capacity for the abutment footing.

Figure 10.1.40 Inspector Checking for Scour

Drainage Systems

Water can build up horizontal pressure behind an abutment. Allowing the water to exit from behind the abutment relieves this pressure. Weep holes, normally 100 mm (4 inches) in diameter, allow water to pass through the abutment. Sometimes abutments have subsurface drainage pipes that are parallel to the rear face of the abutment stem. These pipes are sloped to drain the water out at the end of the abutment.

Check weep holes and subsurface drainage pipes to see that they are clear and functioning. Be careful of any animal or insect nests that may be in the weep holes. Look for signs of discoloration under the weep holes, which may indicate that the weep holes or substructure drainage pipes are functioning properly. Check the condition of any drainage system that is placed adjacent to the abutment that may result in deterioration of the abutment.

Areas Subjected to High Stresses

Closely examine the high bearing zones, high shear zones, and high flexural areas.

High bearing zones include the bridge seats, the abutment stem/footing connection, and the area where the footing is supported by earth or deep foundations. In timber abutments, look for crushing. Look for cracking or spalling in concrete and masonry members. Examine steel members for buckling or distortion.

Horizontal forces cause high shear zones at the bottom of the backwall, and bottom of abutment stem. In timber abutments, look for splitting. Look for diagonal cracks in concrete and masonry. Examine steel members for buckling or distortion.

High flexural moments caused by horizontal forces occur at the bottom of the backwall and abutment stem connection. High flexural moments may be occurring at the footing toe/abutment stem. Moments cause compression and tension depending on the load type and location of the member neutral axis. Look for defects caused by overstress due to compression or tension caused by flexural moments. Check compression areas for splitting, crushing or buckling. Examine tension members for cracking or distortion.

Areas Exposed to Traffic

Check for collision damage from vehicles passing adjacent to structural members.

Damage to concrete abutments may include spalls and exposed reinforcement and possibly steel reinforcement section loss.

Steel abutments may experience cracks, section loss, or distortion which must be documented.

Fatigue Prone Details and Fracture Critical Members

Steel abutments may contain fatigue prone details. Closely examine these details for section loss due to corrosion and cracking. The members of a steel abutment may be fracture critical. See Topic 8.1 for a detailed description of fatigue prone details and fracture critical members.

10.1.4 Design Characteristics of Wingwalls

General

Wingwalls are located on the sides of an abutment and enclose the approach fill. Wingwalls are generally considered to be retaining walls since they are designed to maintain a difference in ground surface elevations on the two sides of the wall (see Figure 10.1.41).

A wingwall is similar to an abutment except that it is not required to carry any loads from the superstructure. The absence of the vertical superstructure load usually necessitates a wider footing to resist the overturning moment or horizontal sliding.

Figure 10.1.41 Typical Wingwall

Geometrical Classifications

There are several geometrical classifications of wingwalls, and their use is dependent on the design requirements of the structure:

- **Straight -** extensions of the abutment wall (see Figure 10.1.42)
- **Flared -** form an acute angle with the bridge roadway (see Figure 10.1.43)
- **U-wings -** parallel to the bridge roadway (see Figure 10.1.44)

Figure 10.1.42 Straight Wingwall

Figure 10.1.43 Flared Wingwall

Figure 10.1.44 U-wingwall

Construction Classifications

There are several construction classifications of wingwalls:

- **Integral** - constructed monolithically with the abutment (see Figure 10.1.45) normally cast-in-place concrete
- **Independent** - constructed separately from the abutment; usually an expansion or mortar joint separates them from the abutment stem (see Figure 10.1.46)

Figure 10.1.45 Integral Wingwall

Figure 10.1.46 Independent MSE Wingwall

Primary Materials

Wingwalls may be constructed of concrete, stone masonry, steel, or timber or a combination of these materials.

Figure 10.1.47 Masonry Wingwall

Primary and Secondary Reinforcement

In a concrete cantilever wingwall, the primary reinforcing steel consists of vertical bars in the rear face of the stem, horizontal bars in the bottom of the footing (toe steel), and horizontal bars in the top of the footing (heel steel) (see Figure 10.1.48). Secondary reinforcement is used to resist temperature and shrinkage.

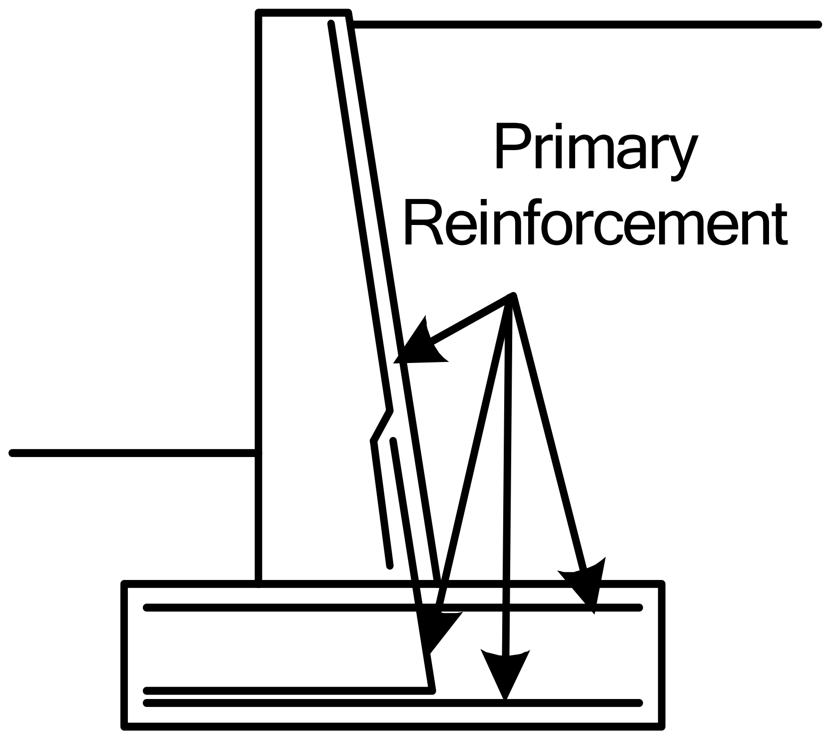

Figure 10.1.48 Primary Reinforcement in Concrete Cantilever Wingwall

10.1.5 Inspection Procedures and Locations for Wingwalls

The inspection procedures and locations for most wingwalls are similar to those for abutments (see Topic 10.1.3). Many of the problems that occur in abutments are common in wingwalls also, including:

- Vertical movement
- Lateral movement
- Rotational movement (see Figure 10.1.49)
- Material defects (see Figure 10.1.50)
- Scour/undermining (see Figure 10.1.51)
- Drainage systems
- Areas subjected to high stresses
- Areas exposed to traffic

Figure 10.1.49 Rotational Movement at Concrete Wingwall

Figure 10.1.50 Deteriorated Concrete Wingwall

Figure 10.1.51 Scour and Possible Undermining of Concrete Wingwall

Material defects to look for include shoulder erosion, cracks, concrete deterioration, stone masonry deterioration, timber decay, and steel buckling (see Figures 10.1.52 to 10.1.55).

Figure 10.1.52 Roadway Shoulder Erosion Behind Wingwall

Figure 10.1.53 Settlement Cracks at Integral Concrete Wingwalls

Figure 10.1.54 Deteriorating Stone Masonry Wingwall

Figure 10.1.55 Timber Wingwall

Wingwall problems are similar to problems in abutments. Refer to Topic 10.1.3 for a detailed description of common abutment problems.

Integral wingwalls should be inspected with the abutments, and they are included in the substructure evaluation and condition rating. However, only that portion up to the first construction or expansion joint is considered. Independent wingwalls should also be inspected, but their condition does not affect the evaluation and condition rating of the substructure. The condition of integral and independent wingwalls should be noted on the inspection form.

10.1.6 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of substructures. The two major rating guideline systems currently in use are the FHWA's *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges* used for the National Bridge Inventory (NBI) component rating method and the AASHTO element level condition state assessment method.

NBI Rating Guidelines

Using NBI rating guidelines, a 1-digit code on the Federal Structure Inventory and Appraisal (SI&A) sheet indicates the condition of the entire substructure including abutments and piers. Rating codes range from 9 to 0, where 9 is the best rating possible. See Topic 4.2 (Item 60) for additional details about NBI Rating Guidelines.

The previous inspection data should be considered along with current inspection findings to determine the correct condition rating.

Element Level Condition State Assessment

In an element level condition state assessment of an abutment or wingwall structure, the AASHTO CoRe element typically is one of the following:

Element No.	Description
215	Abutment – Reinforced Concrete
216	Abutment – Timber
217	Abutment – Other (masonry, steel, etc.)

Some bridge owners use the following CoRe elements for abutments similar to those shown in Figures 10.1.5, 10.1.15, 10.1.16, 10.1.36, and 10.1.38,

Element No.	Description
201	Unpainted Steel Column or Pile Extension (EA)
225	Unpainted Steel Submerged Pile (EA)
230	Unpainted Steel Cap (m or ft)
202	Painted Steel Column or Pile Extension (EA)
231	Painted Steel Cap (m or ft)
204	Prestressed Concrete Column or Pile Extension (EA)
226	Prestressed Concrete Submerged Pile (EA)
233	Prestressed Concrete Cap (m or ft)
205	Reinforced Concrete Column or Pile Extension (EA)
220	Reinforced Concrete Submerged Pile Cap/Footing (EA)
227	Reinforced Concrete Submerged Pile (EA)
234	Reinforced Concrete Cap (m or ft)
206	Timber Column or Pile Extension (EA)
228	Timber Submerged Pile (EA)
235	Timber Cap (m or ft)

The unit quantity for the substructure elements is meters or feet, measured horizontally across the abutment and the total length must be distributed among the four available condition states depending on the extent and severity of deterioration. The unit quantity for columns and piles is each and the total quantity must be placed in one of the available condition states. In all cases, Condition state 1 is the best possible rating. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions.

A Smart Flag is used when a specific condition exists, which is not described in the CoRe element condition state. The severity of the damage is captured by coding the appropriate Smart Flag condition state. The Smart Flag quantities are measured as each, with only one each of any given Smart Flag per bridge.

For settlement of the abutment or wingwall, the “Settlement” Smart Flag, Element No. 360, can be used and one of three condition states assigned. For scour at the abutments or wingwalls, the “Scour” Smart Flag, Element No. 361, can be used and one of three condition states assigned.