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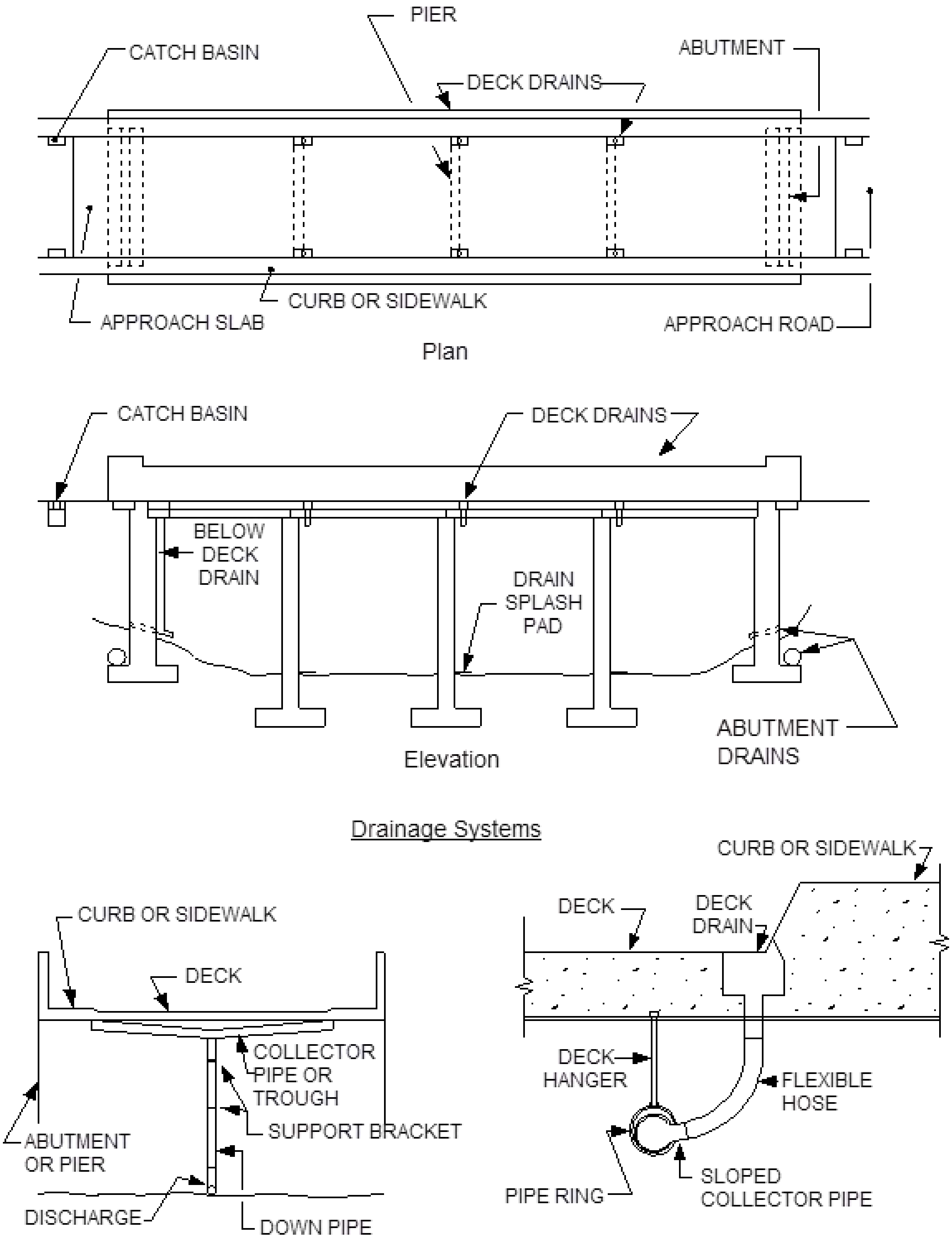

Figure 1.4.5.4 Drainage and Deck Drains

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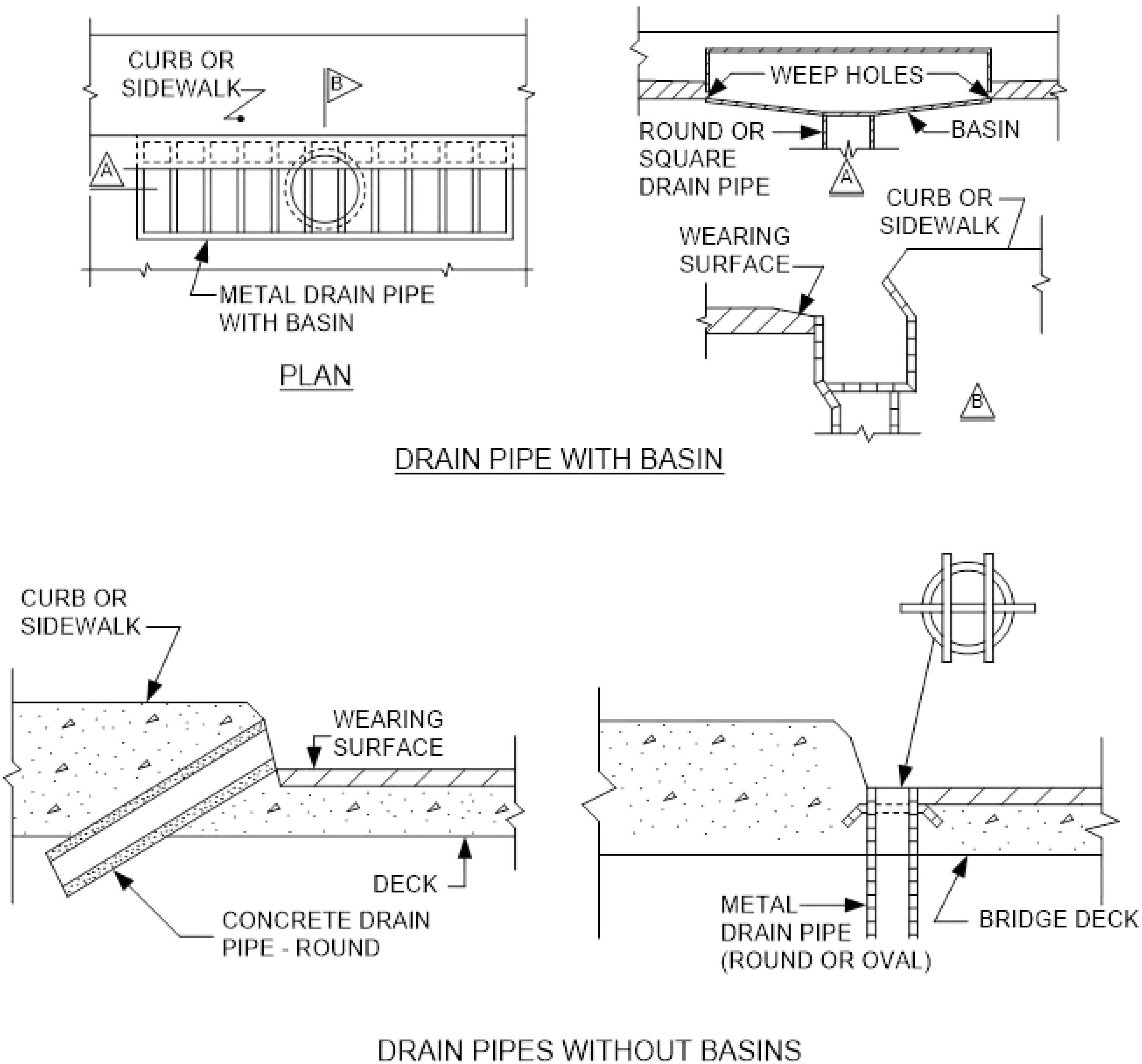

Figure 1.4.5.5 Drainage and Deck Drains (cont.)

1.5 SUBSTRUCTURES

1.5.1 Substructures

The following components are to be considered as substructures:

- Foundations;
- Abutments and piers;
- Retaining walls;
- Soil or rock under reinforced concrete box culverts or below springing lines of soil steel structures.

1.5.1.1 Foundations

Structures are normally supported on either shallow or deep foundations, based upon the depth to rock or soils with adequate capacity to support the loads from the structure.

(a) Shallow Foundations

Shallow foundations, footings, are used where rock or soil with adequate bearing capacity is at or near the ground surface.

Shallow foundations are normally made of mass concrete, reinforced concrete, wood, or masonry. They are occasionally made of reinforced earth, gabions or cribs filled with stones, earth or engineered fill in the case of precast/cast in place box culverts.

Shallow foundations in soils are placed below the local frost depth at the level of competent soil. In streams they are normally buried to protect them against scour and may also have sheet piling as additional scour protection. Foundations on rock do not require frost protection or scour protection.

Typical examples of shallow foundations are shown in Figure 1.5.5.1 and Figure 1.5.5.2.

(b) Deep Foundations

Deep foundations, piles, or caissons are used where rock or soil, capable of carrying the structure loads is overlain by softer material.

Commonly used piles are steel H piles, steel tube piles, timber piles, and reinforced or prestressed concrete piles. Caissons are normally made of large diameter tube piles or box sections made of concrete, steel sheet piles or H piles. They are driven through ground or water for the purpose of placing the foundation at the prescribed depth and, subsequently, become part of the foundation. Steel tubes and caissons may be filled with concrete. Policy changes dating 2026 onward require HPiles to be ‘built-up’ members using steel plate and use of pipe piles were strongly encouraged.

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Piles or caissons may terminate with or without a footing (i.e. pile cap acting as pier footings), which may be located below ground or water level. Where piles or caissons extend to the level of the superstructure they should be inspected as piers or abutments as appropriate.

Typical examples of deep foundations are shown in Figure 1.5.5.3.

1.5.1.2 Abutments

Abutments consist of a number of components, each serving a specific purpose. These components are the foundation, abutment wall, ballast wall, wingwalls and the bearing seats.

In certain structures the abutment or some of its components may be missing, for example:

- abutments are not present in soil steel structures or in some concrete/steel arches;
- in some continuous structures the end span is cantilevered out and has a curtain wall / end diaphragm attached to it that retains the approach fill without the need of an abutment;
- the ballast wall and bearing seats are not needed for rigid frames, box culverts and some concrete arches.

Abutments are commonly made of mass concrete, reinforced concrete, or wood. Occasionally, masonry, steel piles, precast concrete, wire baskets, and reinforced earth have been used for their construction.

Typical examples of abutments are shown in Figure 1.5.5.4 Examples of structures without abutments are shown in Figure 1.5.5.5

1.5.1.3 Piers

Piers consist of a number of components, each serving a specific purpose. These components are the foundation, pier shaft or columns, pier cap and the bearing seats.

Piers are commonly made of reinforced concrete, steel, or wood. Occasionally, mass concrete, prestressed concrete, masonry, steel cribs, or gabions are used in their construction. They can be categorized as follows based on their design and configuration.

Shafts	- concrete or masonry shafts with or without a pier cap;
Bents	- concrete or steel columns with a pier cap;
Columns	- concrete or steel single or multiple columns without a pier cap;
Trestles	- braced wood or steel columns with a pier cap;
Cribs	- wood or steel cribs, empty or filled with stone or earth;
Gabions	- wire baskets filled with stones.

Typical examples of piers are shown in Figure 1.5.5.6.

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1.5.1.4 Retaining Walls

Retaining walls consist of walls with or without foundations.

Retaining walls are commonly made of mass concrete, reinforced concrete, wood. Occasionally, masonry, steel piles, precast concrete, wire baskets, bag mortar and reinforced earth have been used for their construction.

They can be categorized as follows based on their design:

Gravity Retaining Walls	mass concrete, masonry, timber cribs, concrete cribs, steel cribs, wire baskets and bag mortar.
Cantilever Retaining Walls	reinforced concrete, steel sheet piling, post, and lagging (concrete, wood or steel or a combination of these).
Anchored Retaining Walls	Tie-back wall.
Retained Soil System (RSS) / Mechanically Stabilized Earth Walls (MSE)	A proprietary system used as an alternative to the above retaining wall types. RSS includes both vertical, high-performance walls as well as low and medium RSS including gabions and other near vertical (greater than 75 degrees) stabilized and faced slopes.

Typical examples of gravity, cantilevered, anchored retaining walls and RSS are shown in Figure 1.5.5.7 to Figure 1.5.5.11 respectively.

1.5.2 Primary Components

Foundations, abutment walls, and piers are to be considered as primary components.

1.5.2.1 Material Defects of Primary Components

Material defects are as described in Part 2, Section 2.5.

1.5.2.2 Performance Defects of Primary Components

Performance defects of foundations relate to their ability to support the components above them and to transmit the loads imposed on them to the rock or soil without appreciable movements.

Performance defects of abutment walls relate to their ability to provide adequate support to the superstructure and to retain the approach fills without appreciable movements including settlement.

Performance defects of piers relate to their ability to provide adequate support to the superstructure without appreciable movements including settlement.

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Movements of foundations, abutment walls and piers may consist of vertical, longitudinal, or transverse translations or rotations. Some of the common causes for these movements are:

- material defects leading to loss of strength of components;
- overloading from the superstructure;
- excessive earth pressures;
- excessive ice pressure;
- consolidation or failure of the soil;
- scour or erosion of the soil below the foundations;
- Slope failure (embankment slides)
- frost action.

It is important to determine if the component is stable or unstable as indicated by the rate of increase of movement.

Foundation movements of retaining structure may be detected by the observation of the overall structure for lines that seem incongruous with the rest of the structure. It is not unreasonable to document in a report that there are no know deficiencies, to let future inspectors know that deficiencies they are seeing are new.

For a more detailed inspection, the following methods are often useful:

Check the alignment: Any abrupt change or kink in the alignment of the retaining structure may indicate a differential lateral movement of adjacent walls. Older retaining structures are particularly vulnerable to ice pressures which can cause structural misalignment.

Sight along railings: A sudden dip in the rail line is often the result of settlement of a pier or abutment.

Run profile levels along the centerline and/or the gutter lines: This inspection technique will help to establish the existence of any settlement. Normally, this kind of inspection technique will be employed only for large retaining structures or where information concerning the extent and character of differential settlement movement is required.

Check retaining wall faces for plumbness with a transit*:* This inspection method provides an excellent check for the simpler techniques of plumbness determination. An out-of-plumb structure in either direction usually signifies foundation movement; it may also indicate a superstructure displacement. For small retaining structures and for preliminary checks, the use of a plumb bob is an adequate means for determining plumbness.

Observe expansion joints at abutments and walls: Observe the expansion joints for signs of opening or rotating. These conditions may indicate the movement of subsurface soils or a bearing failure under one of the footings.

Observe slabs, walls, and members*:* Cracks, buckling, and other serious distortions should be noted. Bracing, as well as the main supporting sections, should be scrutinized for distortion.

Observe fill and excavation slopes: Slide scarps, fresh sloughs, and seepage are indications of soil movement.

Unbalanced post construction embankment or fills: Embankments should be checked for balance and positioning. Unbalanced embankments can cause a variety of soil movements which can impair the structural integrity of the retaining structure.

1.5.3 Secondary Components

Ballast walls, wingwalls, retaining walls (including RSS/MSE walls) and bearing seats are to be considered as secondary components. The foundations of wingwalls and retaining walls are also to be considered as secondary components.

1.5.3.1 Material Defects of Secondary Components

Material defects are as described in Part 2, Section 2.5.

All concrete portions of the retaining wall should be inspected under this item. The inspection should include the concrete surfaces as well as any joints. Inspect the exposed portion of the concrete foundation. For low and medium performance RSS/MSE walls, the facing is not a solid concrete panel but can be any number of different materials. These types of RSS walls should be inspected under the wall element.

1.5.3.2 Performance Defects of Secondary Components

Performance defects of bearing seats relate to their ability to provide adequate support to the bearings and, as such, are based on the loss of competent bearing area of the bearing seats.

Performance defects of ballast walls, wingwalls and retaining walls relate to their ability to retain the fill behind them without appreciable movements. Movements of the walls may consist of vertical, longitudinal, or transverse translations or rotations. Some of the common causes for these movements are:

- material defects leading to loss of strength of the walls;
- overloading from the superstructure;
- excessive earth pressures;
- excessive ice pressure;
- failure of the soil or foundation;
- scour or erosion of the soil below the footings;
- frost action.

It is important to determine if the walls are stable or unstable as indicated by the rate of increase of the movements.

If the wall or foundation are tilted or have appeared to move, a performance deficiency for tilted/shifted structure should be noted. This can either be noticed at the foundation itself or it may be evidenced by a rotation of the wall structure. Differential settlement may occur in long walls if the properties of the native material vary for a long distance. In such cases the wall will crack vertically since the bearing soil bearing values vary along the wall.

Tilting, forwards or backwards beyond 50 mm in 1 meter values indicate possible foundation failure resulting from:

1. Excessive toe pressure
2. Excessive settlement due to compressible substratum

Wall joints that are to be inspected in this element are construction joints, contraction joints, expansion joints and joints between pre-cast panels. **Joint defects should be recorded using 4m of linear measure equals 1 m^2 of defect.**

The following is a list of wall joint types and their purposes:

Construction joint	It is the vertical or horizontal joints between successive placements of concrete. These joints are keyed so as to resist shear forces
Contraction joint	It is the shallow groves on the face of the wall and running full height of the face slab. They are placed vertically at 25 ft to 40 ft to minimize effects of shrinkage and differential settlement. The steel passes through these joints however the joint is weakened thus permitting a tension crack to take place
Expansion joint	It is placed every 60 to 100 ft longitudinally, in a vertical position, with no steel passing these joints. This joint must permit relative movements of wall on each side of the joint. Joints have flexible type joint filler or water stops inserts
Joints Between Panels	It is joints between panels of RSS/MSE walls to allow for minor movements and settlements

1.5.4 Auxiliary Components

Drainage system shall be considered as auxiliary components.

1.5.4.1 Material Defects of Auxiliary Components

Material defects are as described in Part 2, Section 2.5.12.

1.5.4.2 Performance Defects of Auxiliary Components

A primary cause of retaining wall failure is the additional load imposed by hydrostatic pressure due to saturated soils behind the wall. The design must provide adequate drainage facilities for the site to prevent entrapment of water.

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Drainage from behind the wall can be accomplished by providing *weep holes* (pipes which permit passage of water from the backfill to the front) and/or *longitudinal drains* along the back face of the wall.

Drainpipes should not be allowed to clog since the resulting build-up of water behind the wall will exert hydrostatic pressures for which the wall may not have been designed.

1.5.5 References

1. Railway Bridge Maintenance, Frank Turton, C. Eng., 1972.
2. Design and Construction of Mechanically Stabilized Earth (MSE) Walls – FHWA-HIF-24-002 (2023)
3. FHWA-NHI-10-025 Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II
4. Foundations, Retaining and Earth Structures, 2nd edition, Gregory P. Tschebotarioff, McGraw-Hill Kogakusha, Ltd., 1973.
5. Foundation Design, Wayne C. Teng, Prentice-Hall, Inc.,1962
6. Foundation Analysis and Design, Joseph E. Bowles, McGraw-Hill Book Company, Inc.,1995.

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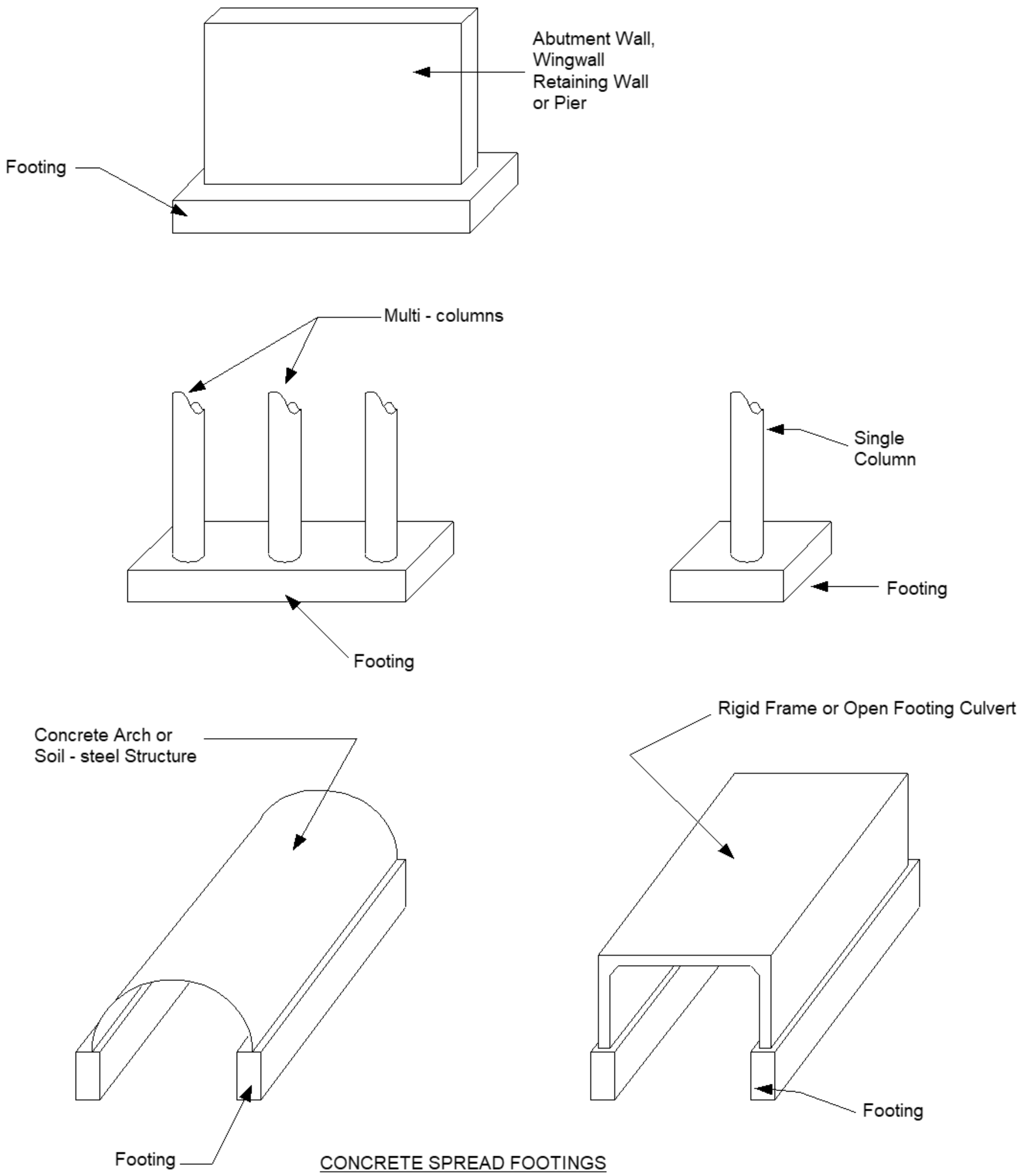

Figure 1.5.5.1 Typical Shallow Foundations

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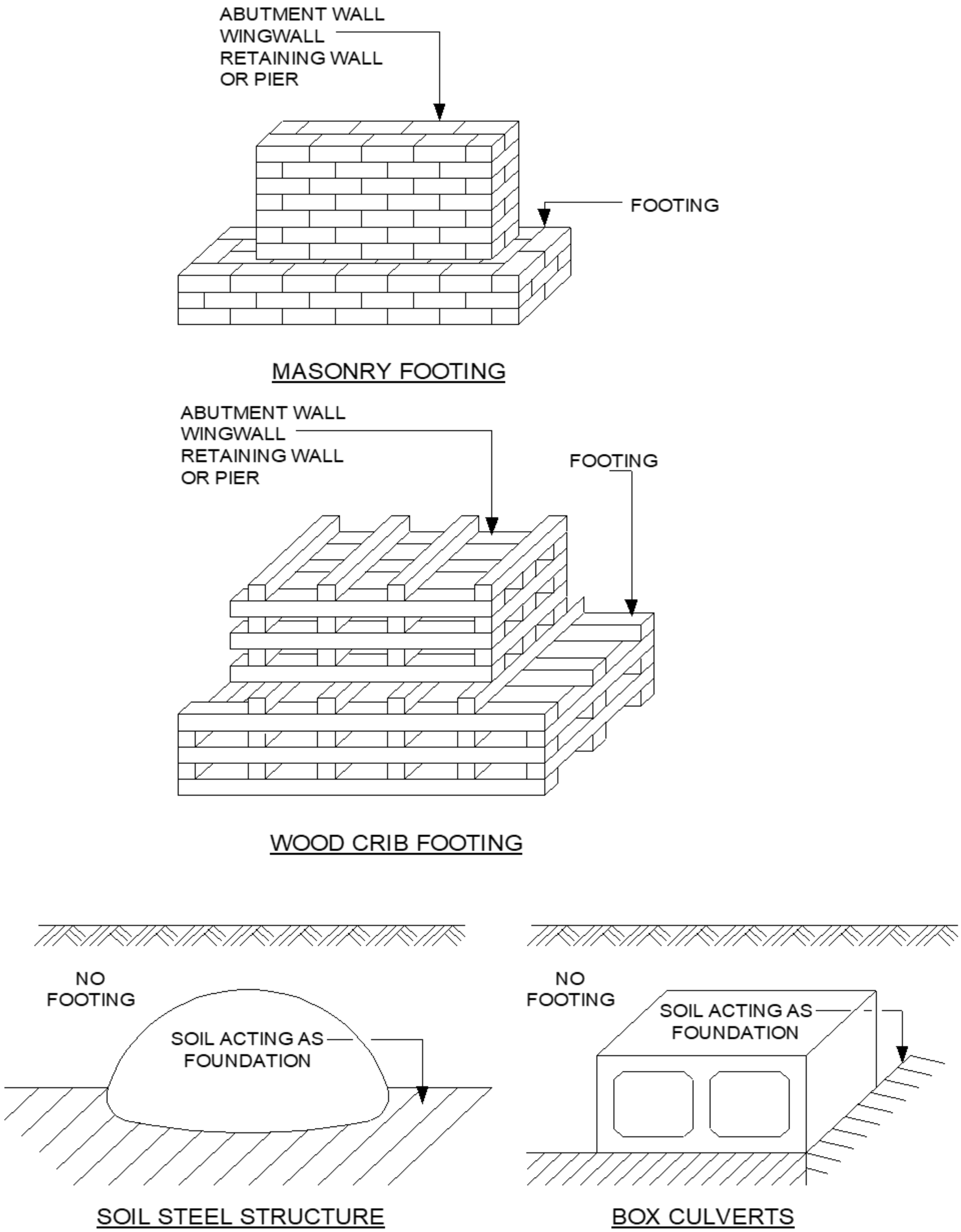

Figure 1.5.5.2 Typical Shallow Foundations (cont.)

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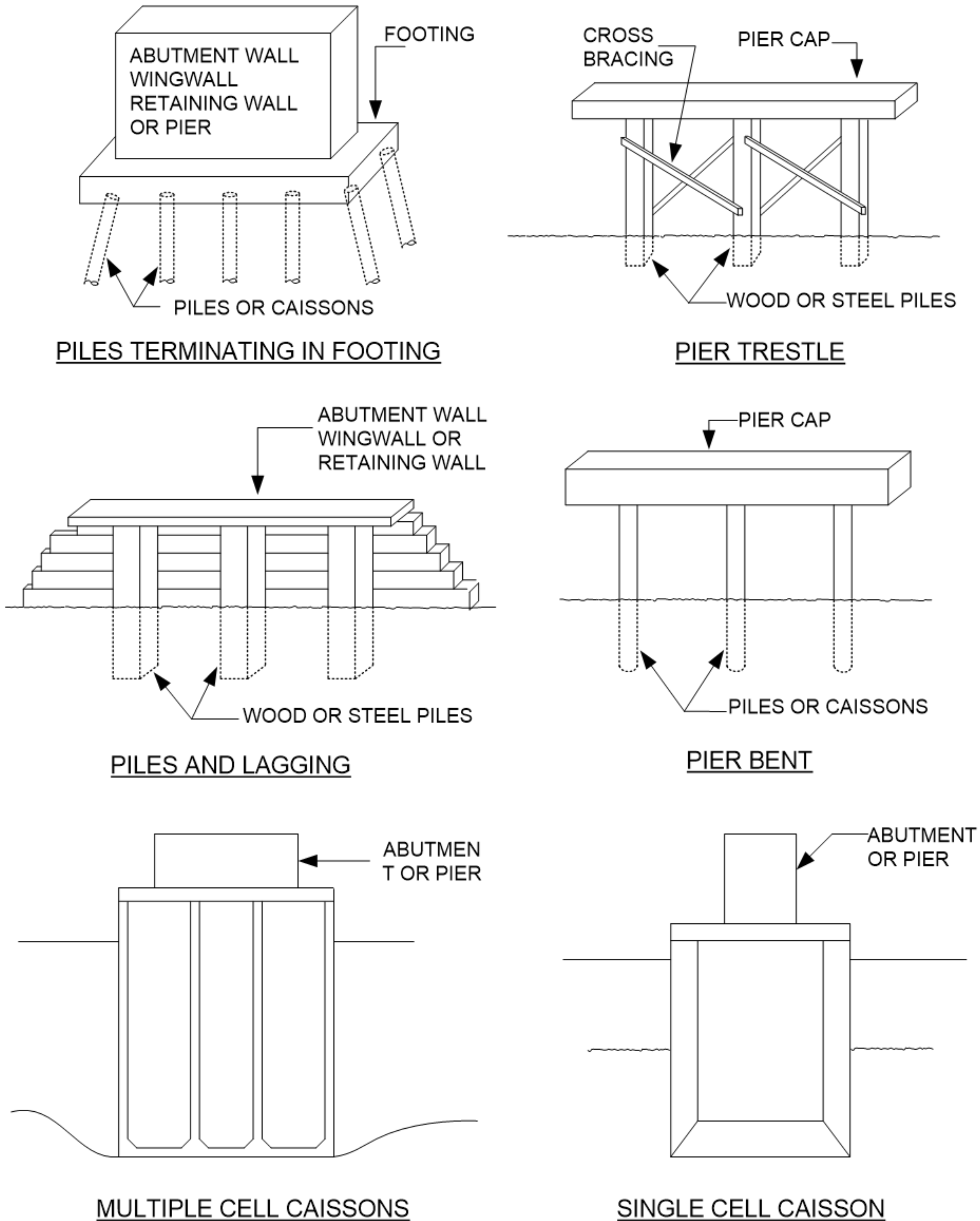

Figure 1.5.5.3 Typical Deep Foundations

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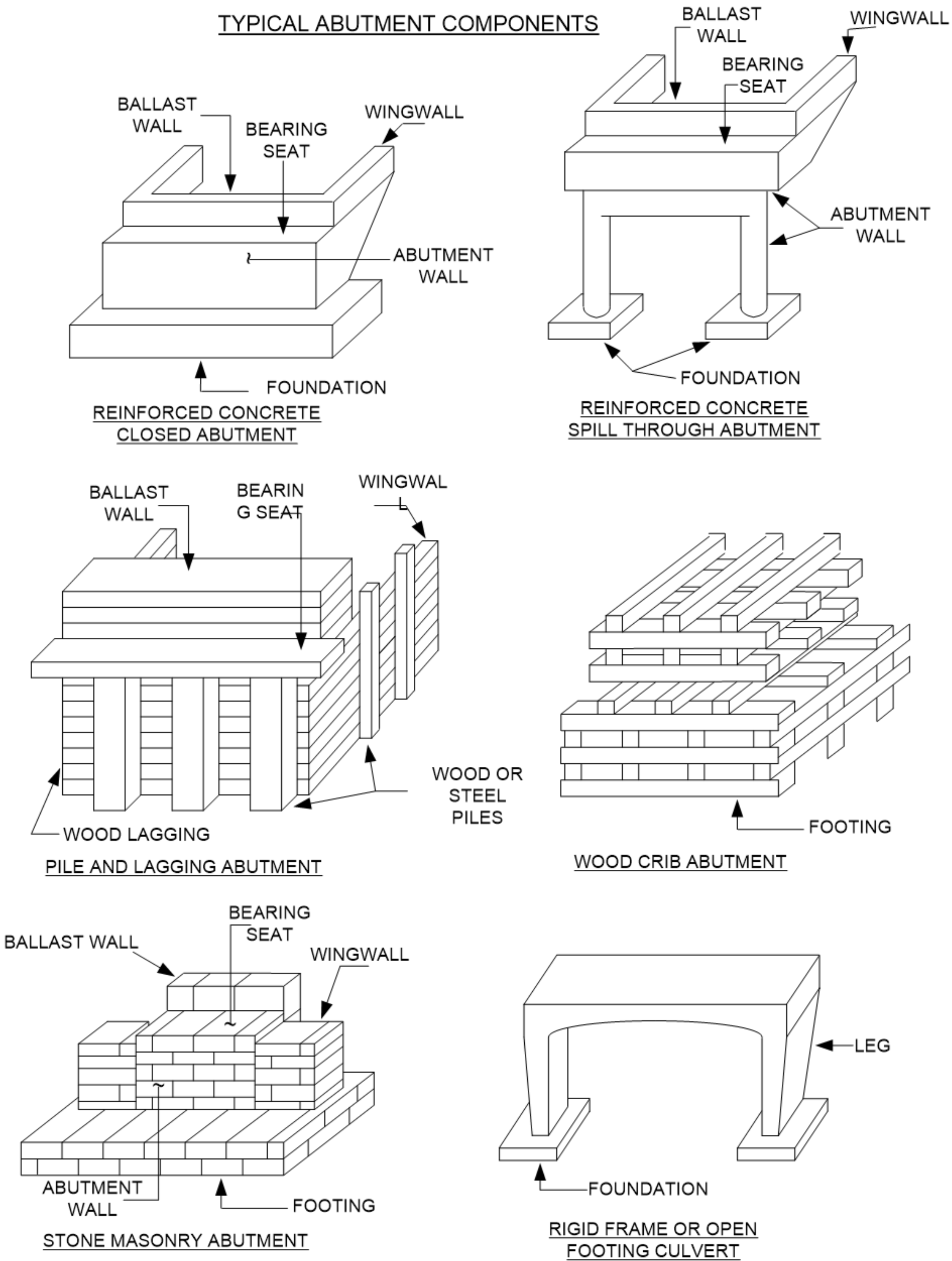

Figure 1.5.5.4 Typical Abutment Components

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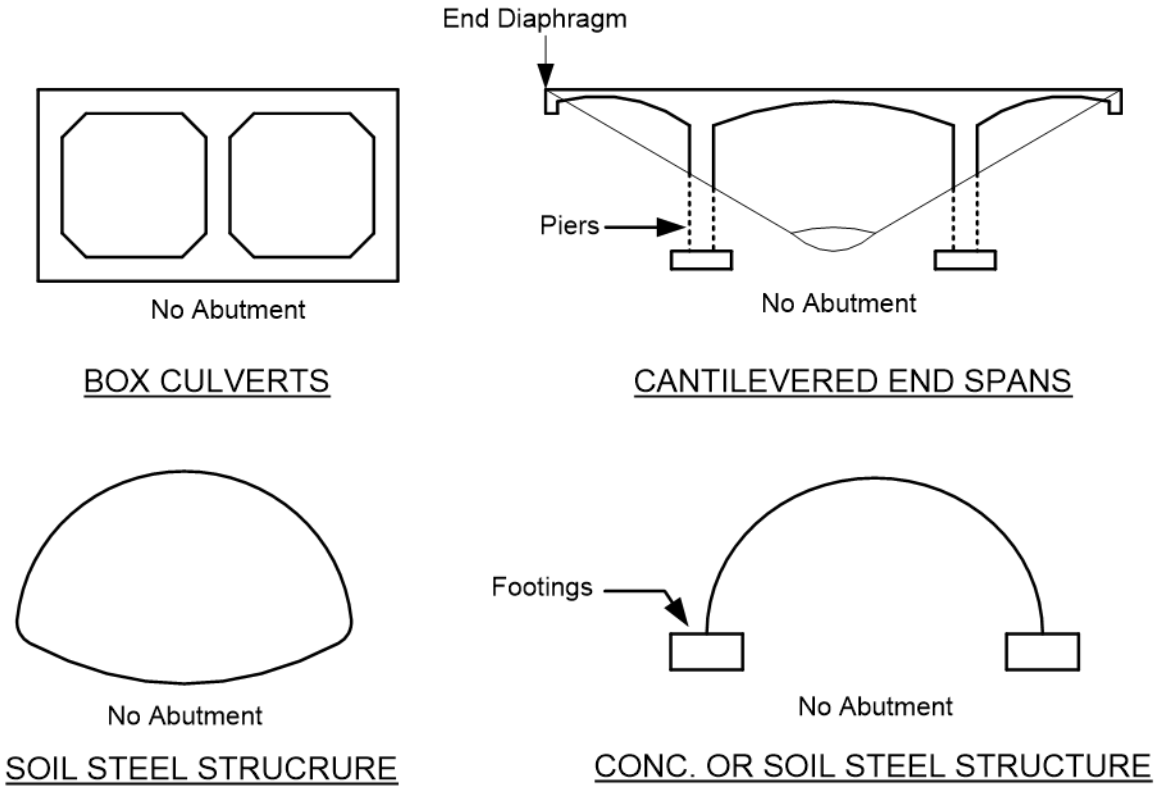
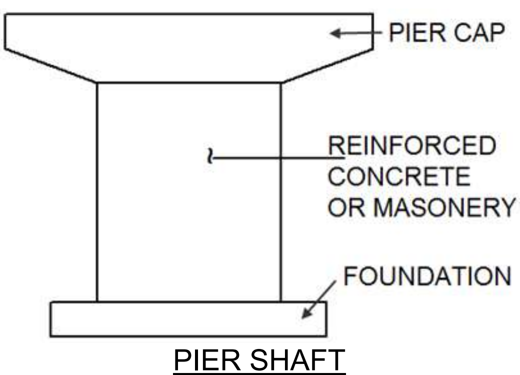
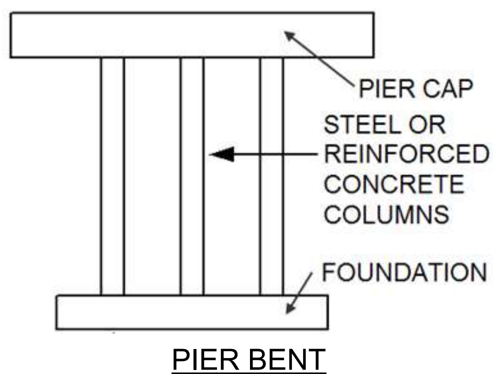


Figure 1.5.5.5 Structures Without Abutments





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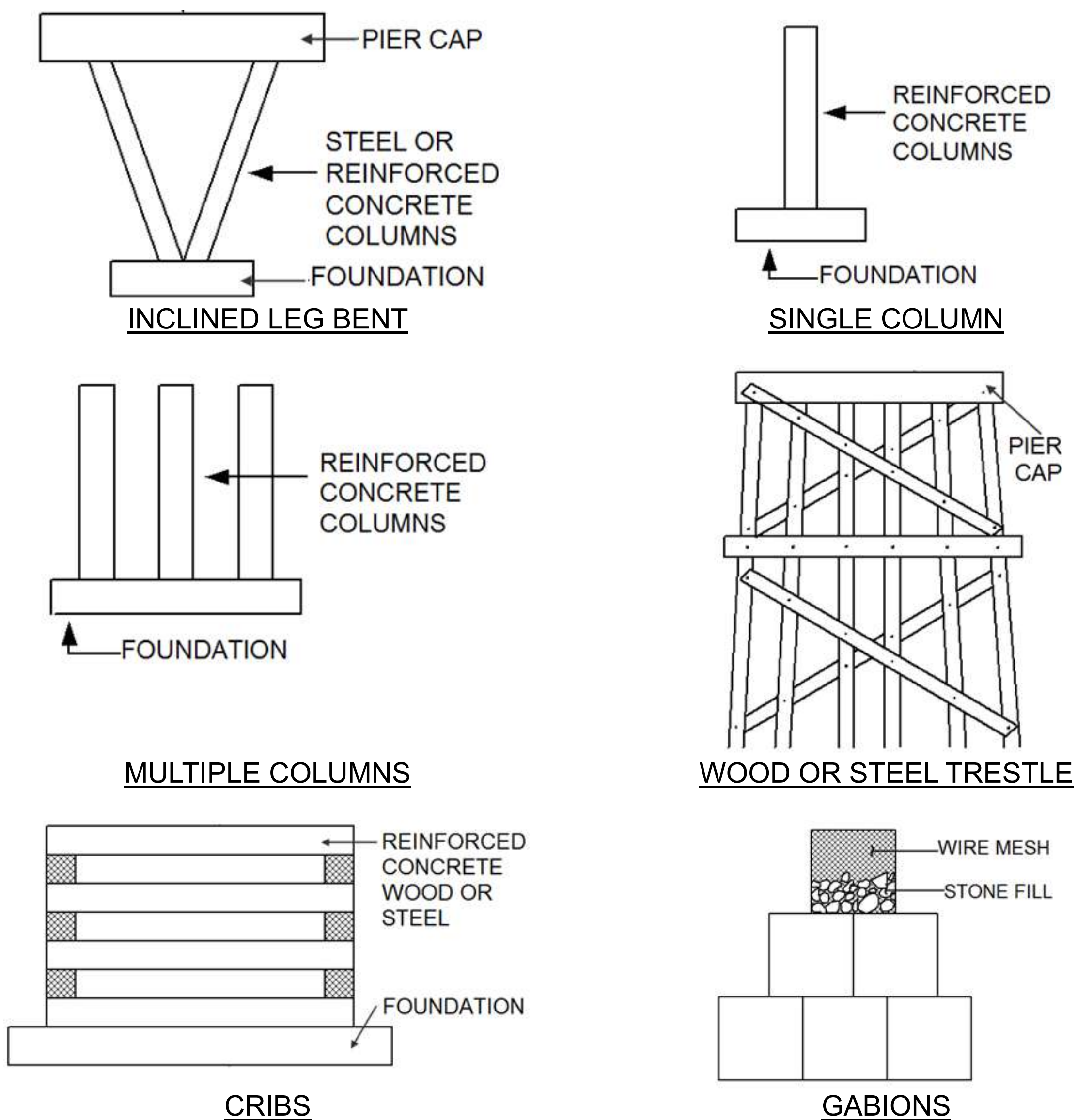

Figure 1.5.5.6 Typical Piers

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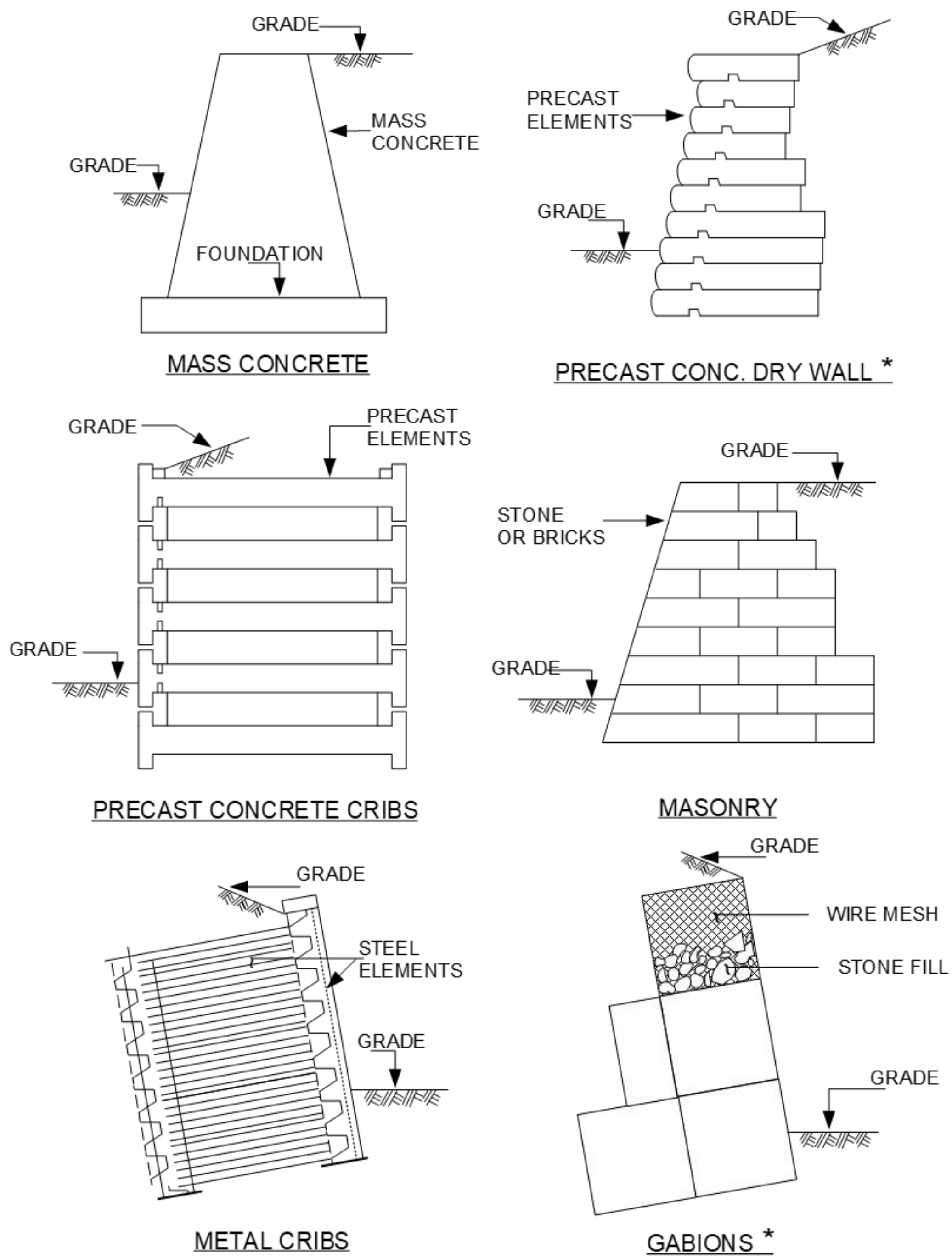

Figure 1.5.5.7 Typical Gravity Retaining Wall

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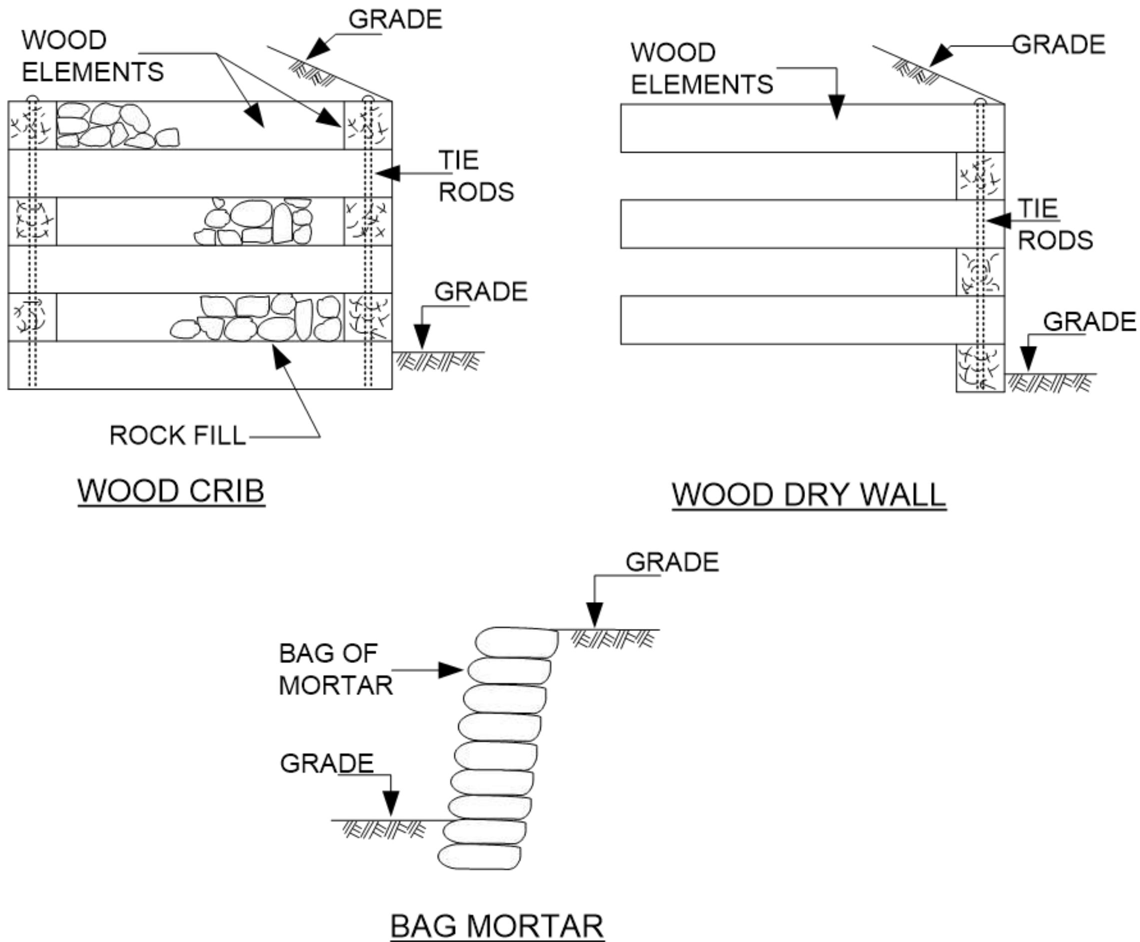

Figure 1.5.5.8 Typical Gravity Retaining Wall (cont.)

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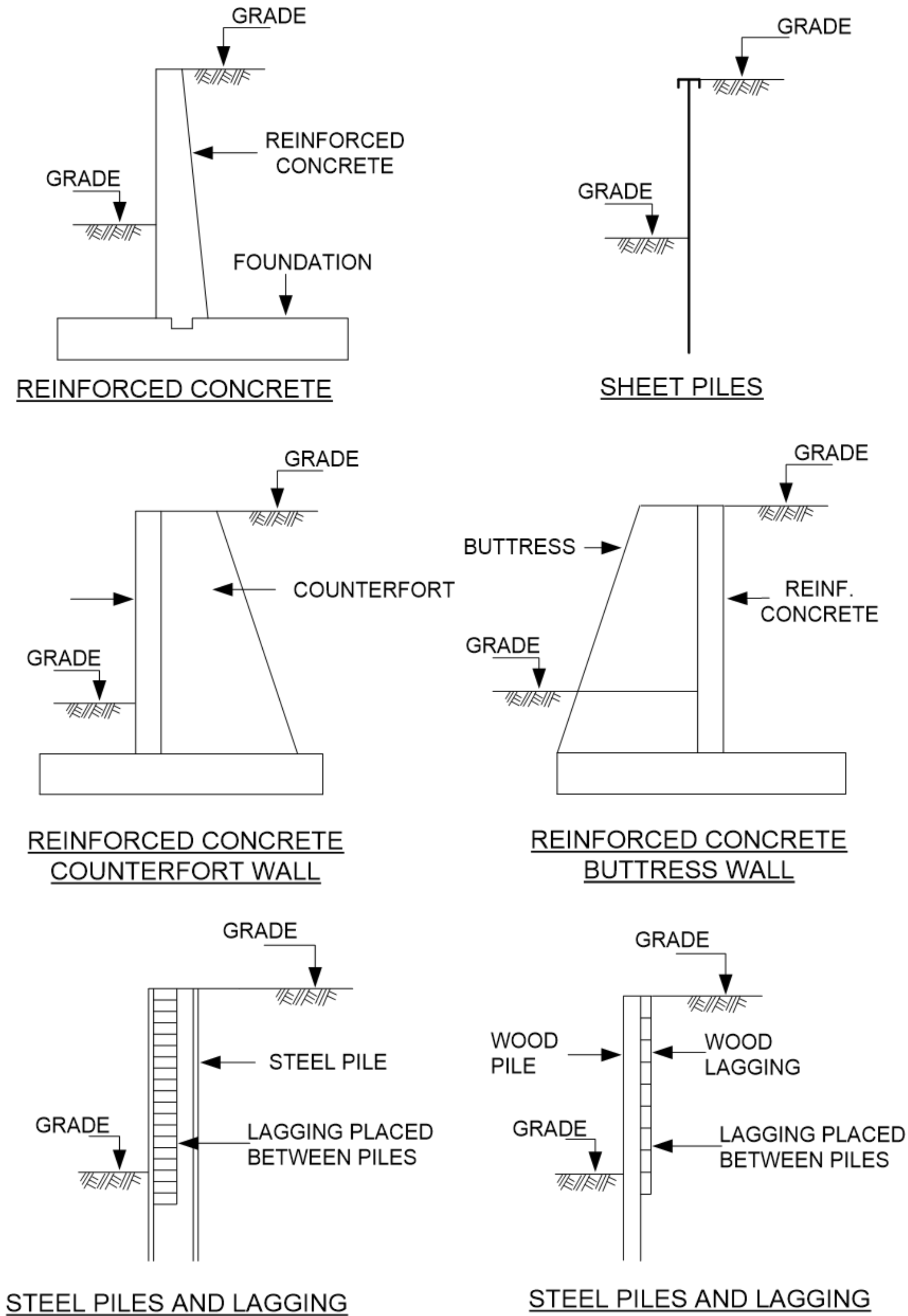

Figure 1.5.5.9 Typical Cantilever Retaining Wall

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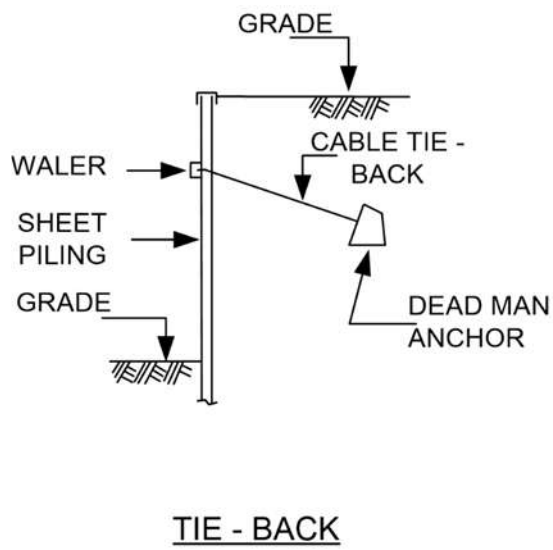

Figure 1.5.5.10 Typical Anchored Retaining Wall

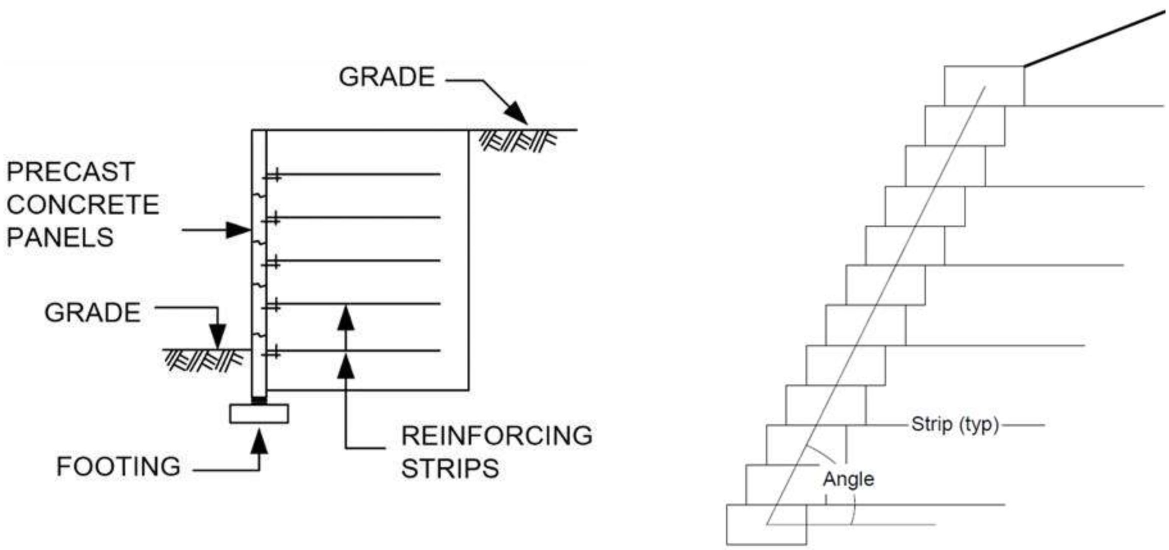

Figure 1.5.5.11 Typical Retained Soil System (RSS)

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1.6 BEARINGS

1.6.1 Bearings

Bearings are normally located at the interface between the superstructure and substructure. In the case of suspended spans, they are located between the suspended span and the supporting superstructure. Bearings are not needed in some structures, for example, culverts, rigid frames and Integral Abutment bridges. Bearings are not used in short span structures where the superstructure rests directly on the substructure.

Bearings are to be considered as secondary components except for the pin and hanger bearing which is to be considered as a primary component.

There are numerous types of bearings made of various materials that have been used in bridges over the years. Bearings usually consist of a number of parts which may include, but is not limited to, the following:

- a levelling pad;
- a base plate sitting on the levelling pad;
- anchor bolts or pins to secure the base plate to the supports;
- the bearing itself;
- retainer bars or pins to prevent transverse movement of the bearing;
- a shoe plate attached to the underside of the superstructure.

Materials used in bearings are steel, rubber, neoprene, polymers, aluminum, or a combination of these. In the past, lead, copper, bronze, or iron were also used.

Bearings are subdivided into two main categories, fixed or expansion bearings, based on their capability for movement. Fixed bearings do not allow for translation but may allow rotation. Expansion bearings allow for translation and may also allow rotation.

Bearings are grouped as follows and are illustrated in Figure 1.6.1.1.

(a) Steel Plate Bearings

Steel plate bearings may be used with or without translational and rotational capabilities depending on the number of parts provided.

Fixity of base plate is provided by anchor bolts or pins.

Translation is provided by steel plate sliding on concrete, bronze, copper or lead or by stainless steel plate sliding on a tetrafluoroethylene (TFE) polymer;

Rotation is provided by a compressible material, usually elastomeric or polyurethane.

(b) Elastomeric Bearings

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Elastomeric bearings provide translation and rotation as a function of their stiffness. Thin pads up to 25 mm thick act as fixed bearings. Thicker pads act as expansion bearings and are often reinforced with steel or aluminum plates.

Fixity is provided by pins or anchor bolts.

Translation is provided by the pad.

Rotation is provided by compression of the pad.

(c) Pot and Disc Bearings

Pot and disc bearings provide rotation. They may also provide translation.

Fixity is provided by anchor bolts or pins.

Translation is provided by the sliding of a stainless steel surface on a tetrafluoroethylene surface.

Rotation is provided by compression of a confined elastomer or polymer disc.

(d) Spherical and Cylindrical Bearings

Spherical and cylindrical bearings provide rotation. They may also provide translation. Cylindrical bearings rotate about the axis of the cylinder, while spherical bearings can rotate about any axis. A TFE sheet is often bonded to the lower surface.

Fixity is provided by anchor bolts or pins.

Translation is provided by sliding of a stainless steel surface on a TFE surface.

Rotation is provided by the sliding of one curved surface over another.

(e) Rocker Bearings

Rocker bearings provide both translation and rotation.

Fixity is provided by anchor bolts or pins.

Translation is provided by tilting or rotation of the rocker.

Rotation is provided by curved top or bottom surfaces.

(f) Roller Bearings

Roller bearings provide translation. They may also provide rotation.

Fixity is provided by anchor bolts or pins.

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Translation is provided by rolling of the rollers on the base plate.

Rotation for single rollers is provided by the curved surface of the roller. For multiple rollers, rotation is provided by a pin connection or curved surface in plate above the roller nest.

(g) Pin and Hanger Bearings

Pin and hanger bearings provide both translation and rotation.

Translation is provided by movement of the hangers about pins in suspended and cantilevered girders.

Rotation is provided by rotation about the pins.

1.6.1.1 Material Defects of Bearings

Material defects in bearings, in addition to those described in Part 2, Section 2.5.9, are:

- lack of lubrication where required;
- cracked or broken parts or plates;
- loose or missing assembly pins, bolts or nuts;
- bent, loose or missing anchor bolts or pins;
- worn pins, rollers, rockers or rolling surfaces;
- electrolytic corrosion of dissimilar materials in contact,
- such as, steel and aluminum or steel and bronze;
- cracks, splits or tears in elastomeric pads;
- elastomer leaking out of pots in pot bearings;
- scored TFE surfaces;
- scratched or damaged stainless steel surfaces;
- pulled out sliding plates.

1.6.1.2 Performance Defects of Bearings

The performance of the bearing is based upon its ability to support and transfer loads from the superstructure to the supports; and, to allow for or restrict translational or rotational movement of the superstructure at the bearing location.

The proper functioning of the bearing is vital to the performance of the structure as malfunction of the bearings may introduce detrimental stresses into other structure components.

The performance of the bearing as it regards movement is based upon either the restriction of movement for expansion bearing or the movement of fixed bearing, and insufficient reserve for anticipated further movement of expansion bearings.

The amount of movement that a structure, and therefore the bearing, may be subject to is a function of the superstructure material, type of construction, expansion length from point of fixity and surrounding air temperature.

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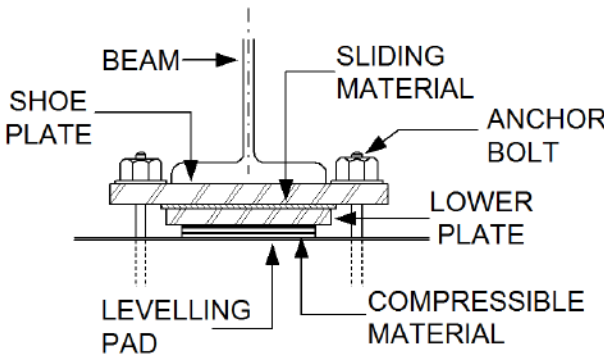
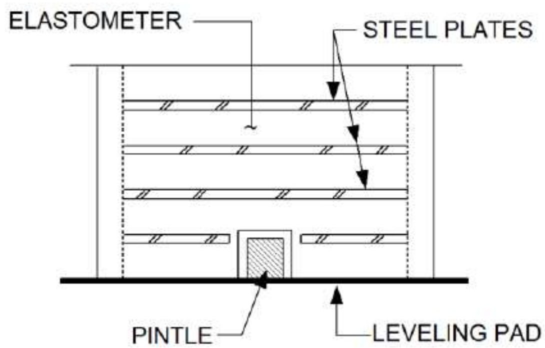
The amount of movement that a bearing can accommodate is a function of the type of bearing and the air temperature at the time the bearing was installed.

It may not be possible to exactly determine the expected movements that a bearing may be subject to or the reserve capacity of the bearing as; the bearing may have been subjected to unaccounted movements, such as, movement of the abutment wall; and the bearing may have been jacked up and relieved of movement during its lifetime.

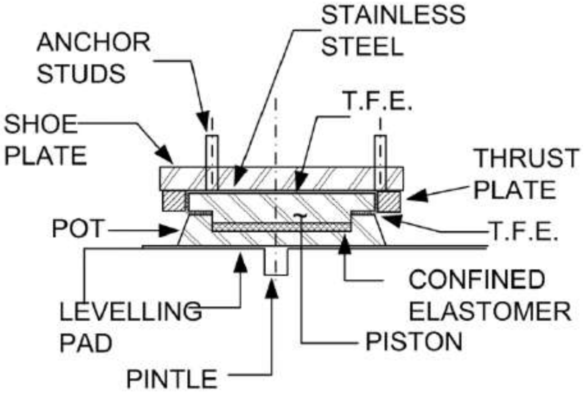
The performance of bearings as it regards load capacity and transfer is based upon the uniform contact of the bearing with the superstructure and substructure over the bearing surfaces; and the ability of the bearing to carry the load without distress.



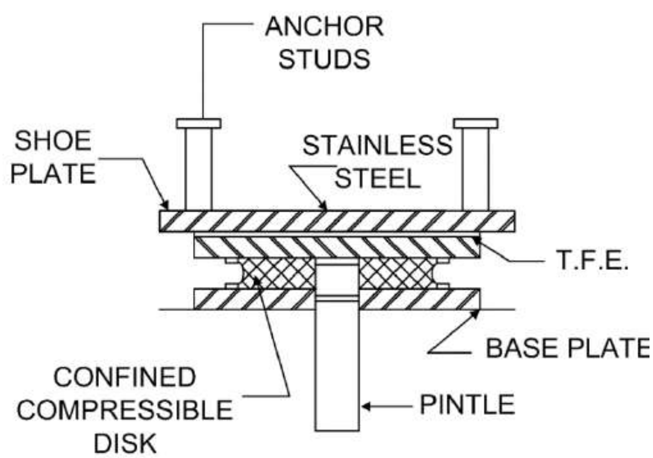
Steel Plate Bearing



Elastomeric Bearing



Expansion Pot Bearing



Multi-Directional Disk Bearing

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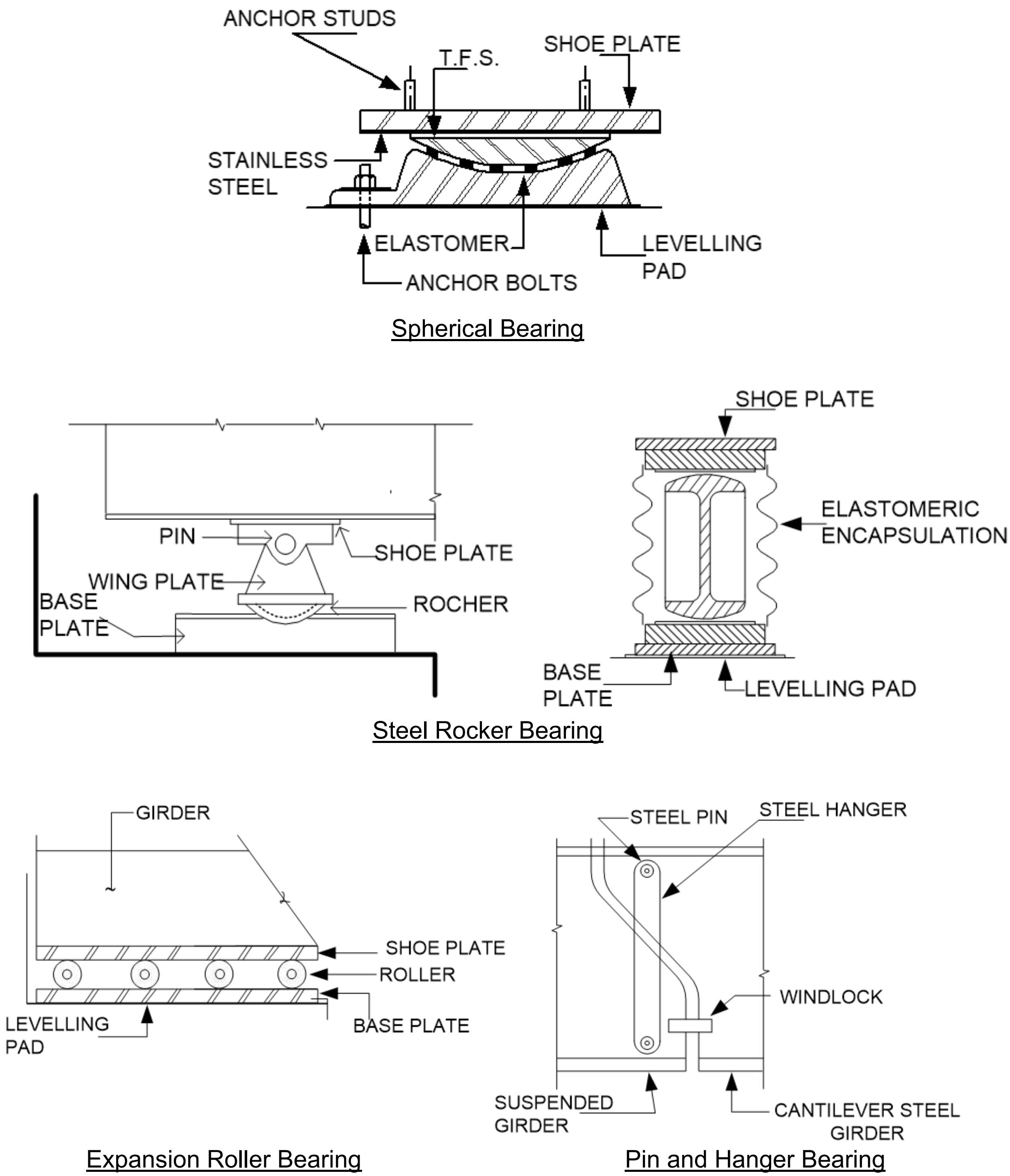

Figure 1.6.1.1 Typical Types of Bearings

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1.7 JOINTS

1.7.1 Joints

Joints in decks may occur between the deck and the abutment, over the piers between adjacent spans, or within the span at suspended spans. Joints are considered to be an Auxiliary Component.

Joints consist of the following parts, all of which may not be present at each joint.

- A gap to allow for movement;
- Armourings and anchorages on each side of the gap to protect the edges of the gap;
- Seals or sealants in the gap to prevent water from leaking through the gap;
- A trough under an open gap to catch drainage and dispose of it away from
- components under the gap.

Joints can be divided into open joints which permit the free flow of water and debris, and sealed joints which prevent the flow of water and debris through the joint. Joints can also be divided into expansion joints which accommodate longitudinal, transverse, vertical and rotational movements and fixed joints which accommodate rotational movements only.

Types of joints commonly used in structures are described below and illustrated in Figure 1.7.1.1 to Figure 1.7.1.6.

(a) Open Joints

Open joints consist of an open gap whose edges may be protected by armouring.

Sliding plate joints have a flat steel plate bridging the gap of an open joint. The steel plate is welded to one armouring and free to slide over the top surface of the other armouring.

Finger plate joints have two steel plates cut and arranged to form a series of intermeshing 'fingers' which are secured to anchorages on each side of the joint and cantilever over the open gap.

Drop-in-T joints have a "T" section bridging the open gap and supported on the armouring on each side of the joint.

(b) Poured-In-Place Joints

Paved-over joints consist of any joint that has been paved over with asphalt pavement. To prevent random cracking of the asphalt pavement over the joint a groove is sometimes cut or formed in the pavement and filled with a sealant.

Hot or cold poured bituminous or mastic asphalt joints consist of an inert filler placed in the joint gap to below the level of the finished grade, and a hot or cold poured bituminous or mastic

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asphalt sealant filling the remaining gap to the finished grade. It may be used with asphalt or concrete pavements.

Cold poured polyurethane joints consist of a formed groove in a concrete pavement which is filled with a cold poured polyurethane compound. This material is not used with asphalt pavements because of incompatibility between the bituminous and polyurethane materials.

Hot poured mastic asphalt systems consist of a plug seal placed in the joint gap and an adhesive waterproof membrane hot poured over the joint for a distance of about 450 mm on each side of the gap. Alternating layers of hot poured mastic asphalt and reinforcing mesh are then placed over the joint up to the level of the adjacent asphalt or concrete pavement. Additional hot poured rubberized material is also sometimes poured into grooves cut over the joint and between the mastic asphalt and adjacent roadway surface.

(c) Compression Seal Joints

Elastomeric seal joints consist of a precompressed extruded elastomeric seal bonded to the sides of the joint gap whose edges may be protected by armouring.

Ethylene vinyl acetate joints consist of a precompressed ethylene vinyl seal (looks like foam) bonded to the sides of the joint gap whose edges may be protected by armourings.

These joints allow for movements by changes in the amount of the precompression of the seal.

(d) Elastomeric Cushion Joints

Elastomeric cushion joints consist of a moulded steel reinforced elastomeric assembly that spans over the gap. These joints allow for movements by deformation of the moulding.

(e) Multiple Seal (Modular) Joints

Multiple seal (modular) joints consist of two or more elastomeric seals placed between three or more steel separation beams which are placed on steel support beams spanning across the joint gap. These joints are used where large movements are required.

(f) Strip Seal Joints

Strip seal joints consist of an elastomeric seal that is held in place by one of the following methods:

- press fitted into preformed armourings;
- vertically bolted down with steel plate hold downs;
- vertically bolted down and the seal is integral with elastomeric armourings;
- horizontally bolted in and has steel armourings;
- clamping devices with stop bars.

These joints allow for movement by the flexing of the elastomeric seal.

1.7.1.1 Material Defects of Joints

Material defects of joints in addition to those described in Part 2, Section 2.5.10 and 2.5.11 are:

- corrosion and delamination of steel components;
- pulling away or popping out of the seal or sealant;
- cracks, splits, tears or holes in the seal or sealant;
- loose or missing sections of the seal or sealant;
- abrasion, wear or aging of the seal or sealant;
- compression set or loss of resiliency of the seal or sealant;
- loss of bond between the seal or sealant and the adjacent pavement;
- shrinking away of the sealant from the adjacent pavement;
- loose, broken or missing bolts, nuts, washers or other anchorage devices;
- loose, bent, cracked, broken, missing or damaged finger plates, sliding plates, extrusions, support components or armourings;
- cracking of welds and welded connections;
- cracking, spalling or breaking up of the concrete, asphalt, or other material adjacent to the joint;
- softening or shifting of mastic asphaltic materials.

1.7.1.2 Performance Defects of Joints

The performance condition rating of joints is based upon their ability to:

- accommodate the movements of the superstructure;
- prevent the leakage of roadway drainage through the joint in the case of sealed joints;
- maintain the continuity of the roadway surface and support wheel loads.

The performance of joints as regards movement is based upon the restriction to movement and evidence of insufficient reserve for anticipated further movement.

The amount of movement that a structure and, therefore, joint may be subject to is a function of the superstructure material, type of construction, expansion length from point of fixity and surrounding air temperature.

The amount of movement that a joint can accommodate is a function of the type of joint, and the air temperature and joint gap set at the time of installation.

It may not be readily possible to determine the exact amount of movement that a joint may be subject to or the capacity of the joint for movement as complete information on structure movements and joint capacity is often not directly available at the time of inspection. However, the relative size of the joint gap can be assessed with respect to the expansion length from point of fixity and air temperature at the time of inspection.

An incorrect joint gap is likely a symptom of improper functioning of the bearings, or of movements of the abutments, pier, or foundation. The inspector shall measure and record the joint gap and air temperature at the time of inspection.

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The performance of joints as regards roadway continuity is based upon the adverse effects that the misalignment of the joint components on either side of the joint may present to traffic.

Vertical misalignment can result in a bumpy ride across the joint and a potential hazard of loss of vehicle control. Vertically misaligned joints are also subject to damage by snow-plows.

Horizontal misalignment can result in binding or jamming of the joint and tearing of the joint seal or sealant.

The performance of joints as regards water tightness, in the case of sealed joints, is based upon the extent of leakage of roadway drainage through the joint. Joint leakage can result in serious deterioration of the joint materials and other structure components located below the joint.

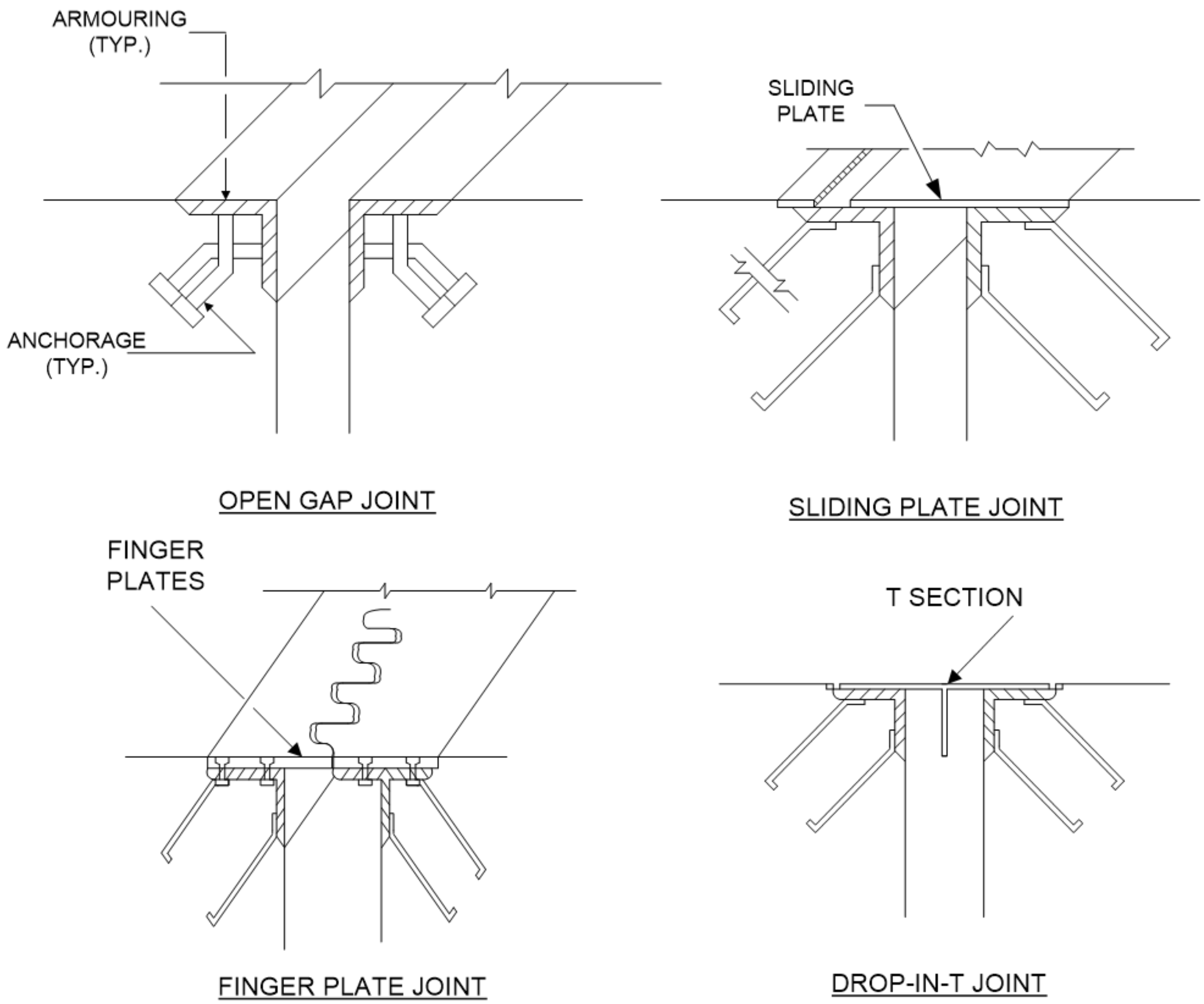

Figure 1.7.1.1 Open Joints

PART 1 – TECHNICAL INFORMATION

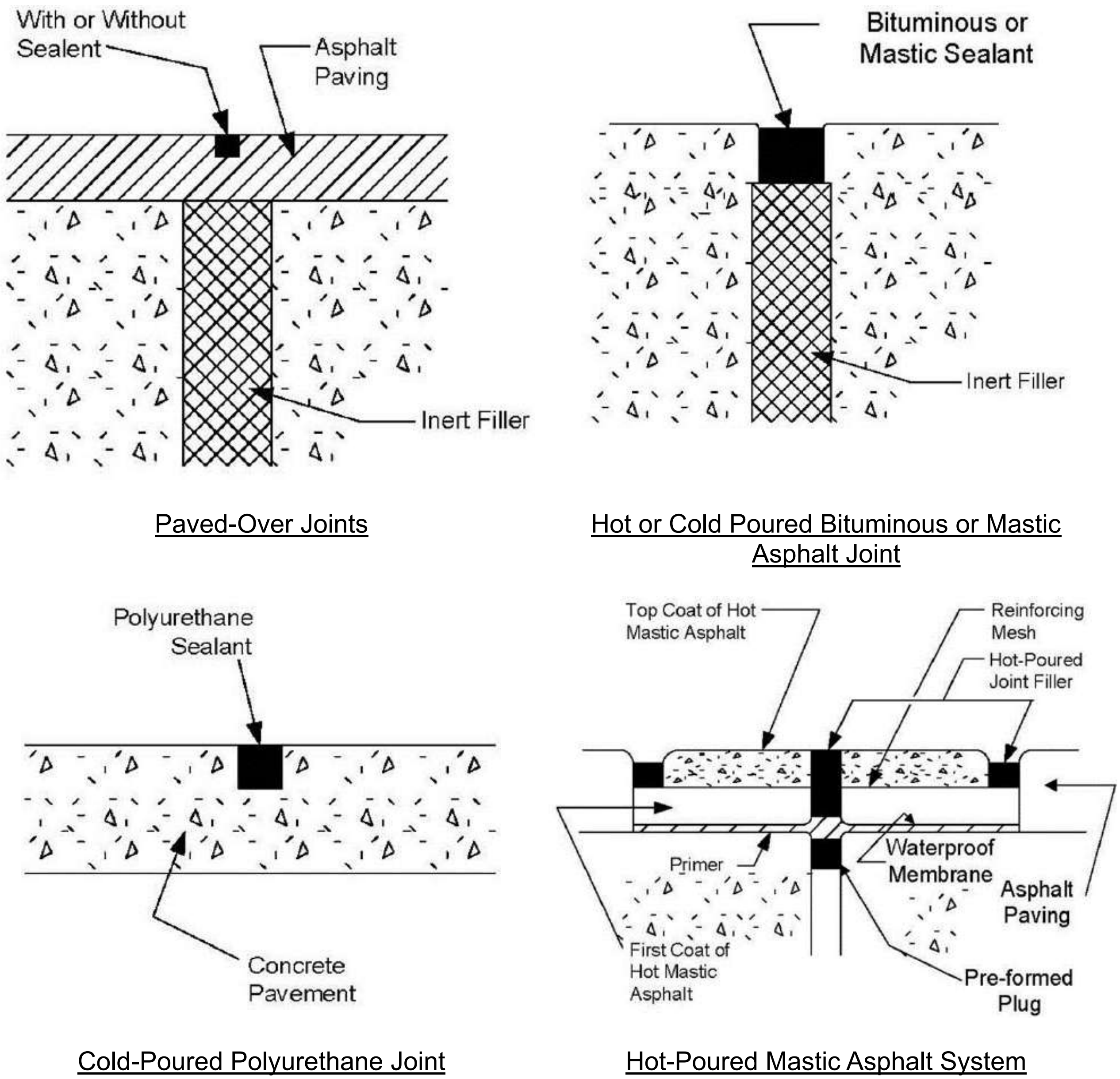

Figure 1.7.1.2 Poured-In-Place Joints

PART 1 – TECHNICAL INFORMATION

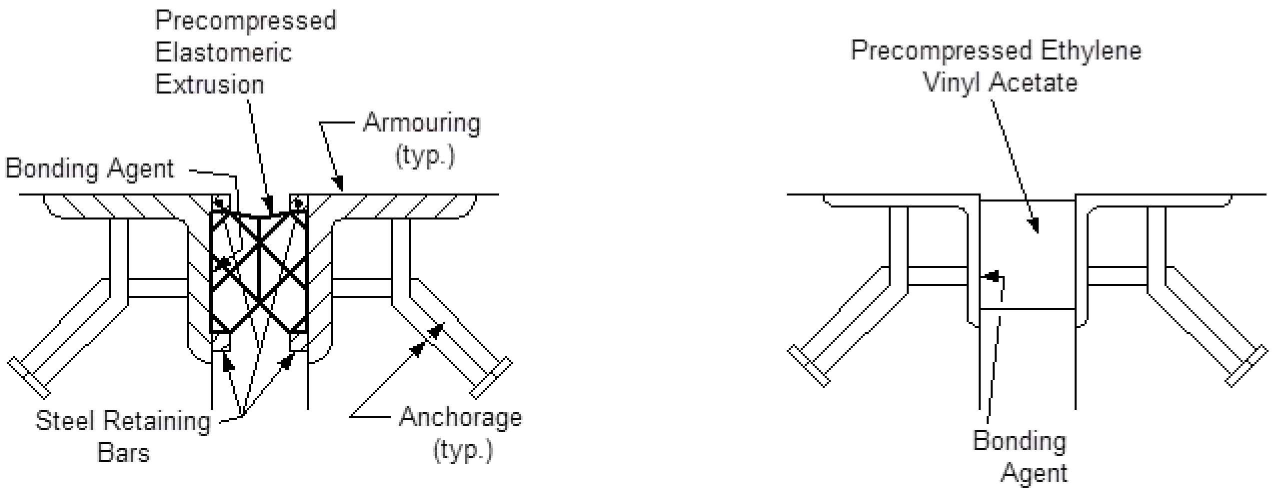

Figure 1.7.1.3 Compression Seal Joints

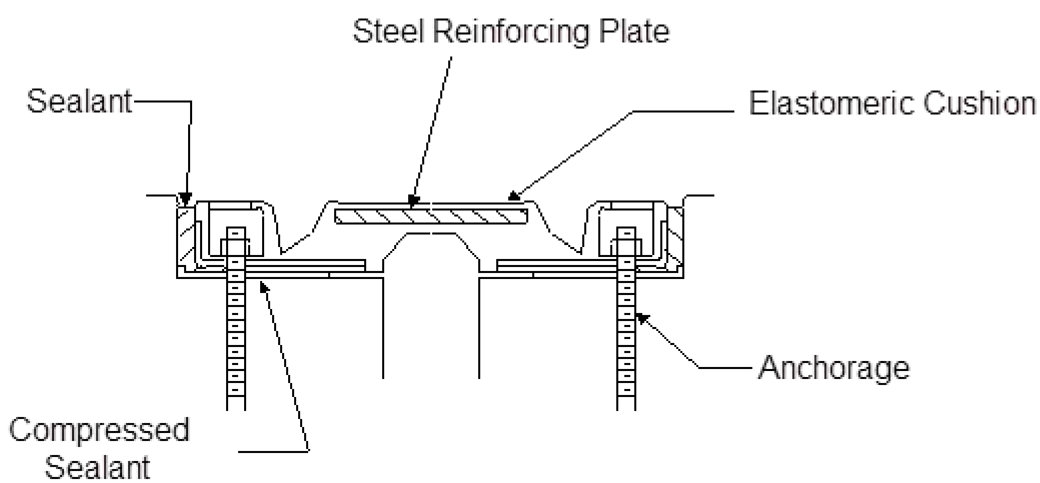

Figure 1.7.1.4 Elastomeric Cushion Joints

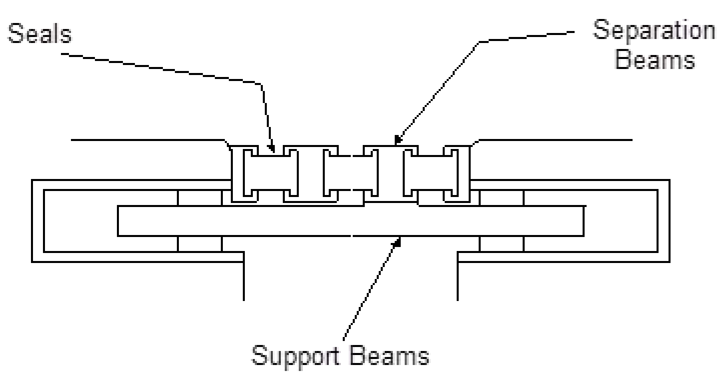

Figure 1.7.1.5 Multi-Seal Joints

PART 1 – TECHNICAL INFORMATION

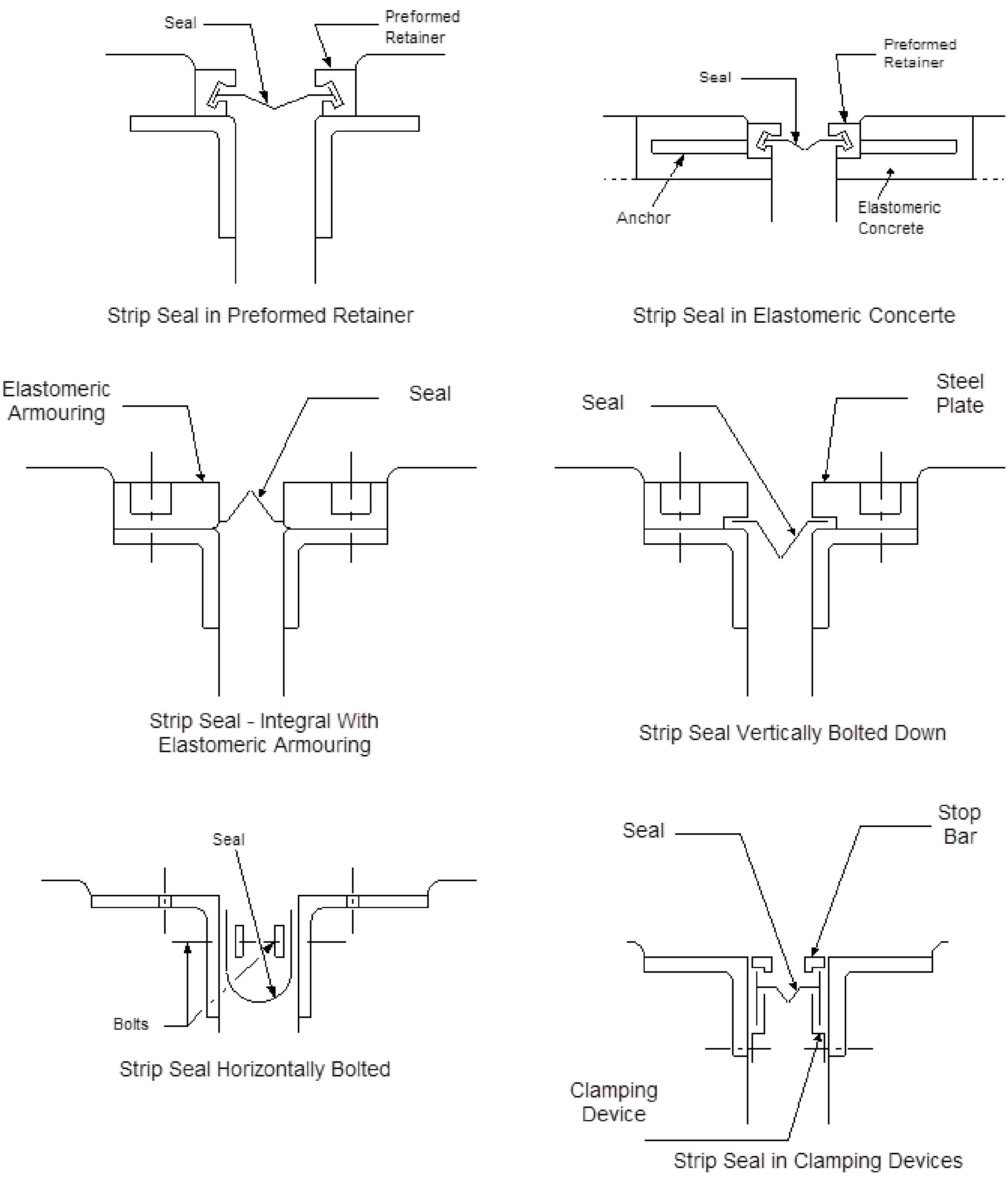

Figure 1.7.1.6 Strip Seal Joints

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1.8 RAILING SYSTEMS

1.8.1 Railing Systems

Railing systems are to be considered as secondary components as they do not normally contribute to the capacity of the structure, however, there are some structures in which the parapet walls also act as the main beams. In those structures the parapet walls shall be considered as primary components.

Railing systems are located at the outermost side limits of the roadway or sidewalk and may also be located along the median for separation of two-way traffic or adjacent to multi-use paths. Railing systems may also be used to protect cyclists in which case there is a minimum height requirement.

Railing systems, post anchorages and rail connections are described below and illustrated in Figure 1.8.1.1 to Figure 1.8.1.6.

(a) Parapet Walls

Parapet Walls are rectangular reinforced concrete walls. They commonly support posts and two tube rails or other rail configurations on them.

(b) Barrier Walls

New Jersey type barrier walls are reinforced concrete walls with a sloping front face. Barrier walls on approaches may not be reinforced. Barrier walls 800 mm high are provided with a top tube rail. Barrier walls 1025 mm high are not provided with a tube rail.

International Barrier Company (IBC) barrier walls are free standing zinc- galvanized steel structures of cold formed profiles supported by interior steel bulkheads and covered by galvanized steel lids. The exterior of the IBC barrier may be vinyl coated. The interior of the IBC barrier is typically filled with sand or gravel.

(c) Railings

Railings consist of posts and rails and may be latticed, barred, balustered, or another open web configuration. Railings have been commonly used in conjunction with curbs and sidewalks on structures with low volume or low speed traffic; and, on structures built before about 1960. Their use was discontinued around that time on structures on King’s highway due to the greater protection provided by the introduction of parapet walls and, later, barrier walls.

The following posts and railings are commonly encountered:

- concrete posts and concrete rails;
- concrete posts and steel rails;
- concrete posts and aluminum rails;
- concrete posts and steel flex-beam rails;

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- steel posts and steel rails;
- steel posts and cable rails;
- steel I-posts and steel box beam rails;
- steel grillages;
- corrugated steel box filled with sand;
- aluminum posts and aluminum rails;
- wood posts and wood rails;
- wood posts and steel flex-beam rails;
- wood posts and steel cables.

In railings using cables, splices may be used to join lengths of cable. End fittings and anchor blocks may also be provided to allow for tensioning of the cables.

(d) Splash Guards and Multi-Use Path Barriers

Splash Guards and multi-use path barriers are designed to protect pedestrians and railings from vehicular salt and water splash; and also serve to guide pedestrian traffic. Splash guards are typically made from concrete, steel, aluminum, or plastic.

(e) Post Anchorages

The method of anchoring posts depends on the post material and on the time of installation of the post relative to the construction of the deck or structure component to which it is connected.

Reinforced concrete posts are usually cast monolithically with the deck, curb, or sidewalk, or are, subsequently, cast around reinforcing extending from them.

Steel posts are anchored by direct embedment or by anchor plates and bolts. Embedded posts are often set into a steel socket and caulked with hot poured sulphur and lead wool or grouted with non-shrink grout. Anchor plates and bolts are generally used when the post is installed on an existing structure component.

Square hollow steel posts commonly used for steel railings were often partially filled with concrete with a drainage hole made through the side of the post, just above the level of the concrete, to prevent bursting of the post due to the freezing of entrapped water. The top of the post was capped to prevent the entry of water.

Aluminum posts are secured to the deck, curb, or sidewalk by anchor bolts. Nylon washers are required between the aluminum base plate and steel anchor bolts.

Wood posts are usually bolted to the side of the structure, or bolted in steel anchor shoes which are bolted down to the deck, curb, or sidewalk.

(f) Rail Connections

Rails are secured to posts by bolts, set screws, nails, or reinforcing steel, depending on the combination of rail and post material:

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- steel rails used with steel, concrete or wood posts are usually bolted to the post;
- steel rails sometimes pass through pre-drilled holes in steel posts;
- aluminum rails used with aluminum or concrete posts are usually bolted to the posts;
- concrete rails used with concrete posts are cast monolithically with the post, or may be precast;
- wood rails used with wood posts are usually nailed or bolted to the post;
- steel cable rails used with wood or steel posts are usually stapled to wood posts; and,
- bolted to or pass through pre-drilled holes in steel posts.

Sleeves are provided between sections of continuous tube rails, and slotted holes are provided at bolted rail splices and rail-to-post connections to allow for: thermal expansion and contraction of the rail, structure movements, and construction tolerances. These provisions do not apply for cable rails, for all concrete railing systems, or for all wood railing systems.

The ends of tube rails are capped to prevent water from entering and causing corrosion inside the rail.

1.8.1.1 Material Defects of Railing Systems

Material defects are as described in Part 2, Section 2.5. In addition, defects in railings using cables are:

- Broken wires or entire cable;
- Loose cables or inadequate cable tension;
- Loose or corroded splices or fittings.

1.8.1.2 Performance Defects of Railing Systems

The performance of barrier walls and railings is based upon their ability to safeguard and guide vehicular traffic and pedestrians along the structure; and, to deter the accidental passage of vehicles over the side of the structure, or into oncoming traffic.

The performance of the top rail on parapet walls, barrier walls, and railings is based on its ability to provide a handrail for pedestrians, to withstand or absorb some vehicular impact and to provide lateral support for some types of railings.

The performance of splashguards is based upon the protection provided to pedestrians or railing systems against salt and water splash directed by vehicles passing in adjacent lanes.

The performance of railing systems shall also be based upon their present condition with regards to their ability to meet the safety standards and other requirements in effect at the time they were originally installed.

PART 1 – TECHNICAL INFORMATION

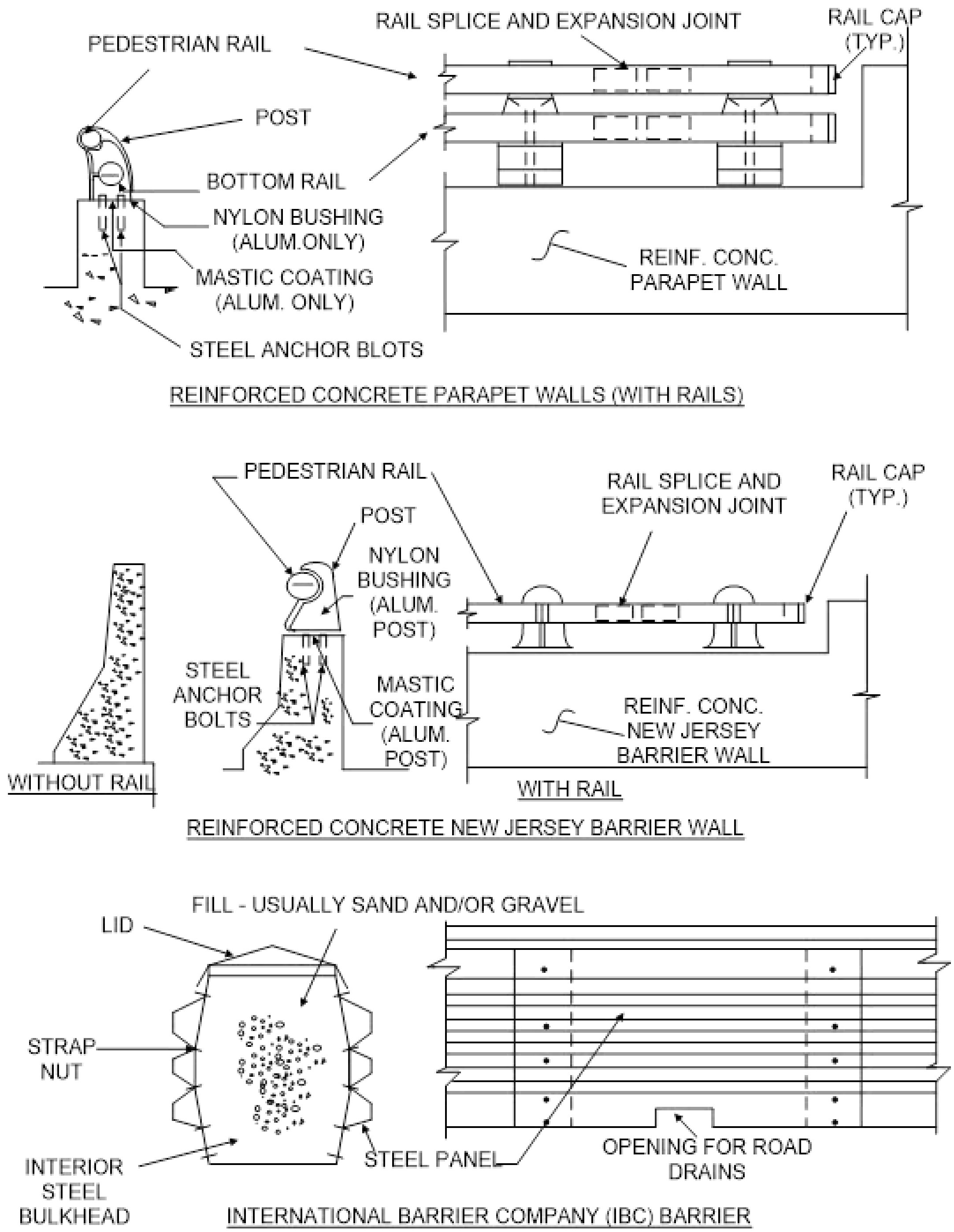


Figure 1.8.1.1 Railing System

PART 1 – TECHNICAL INFORMATION

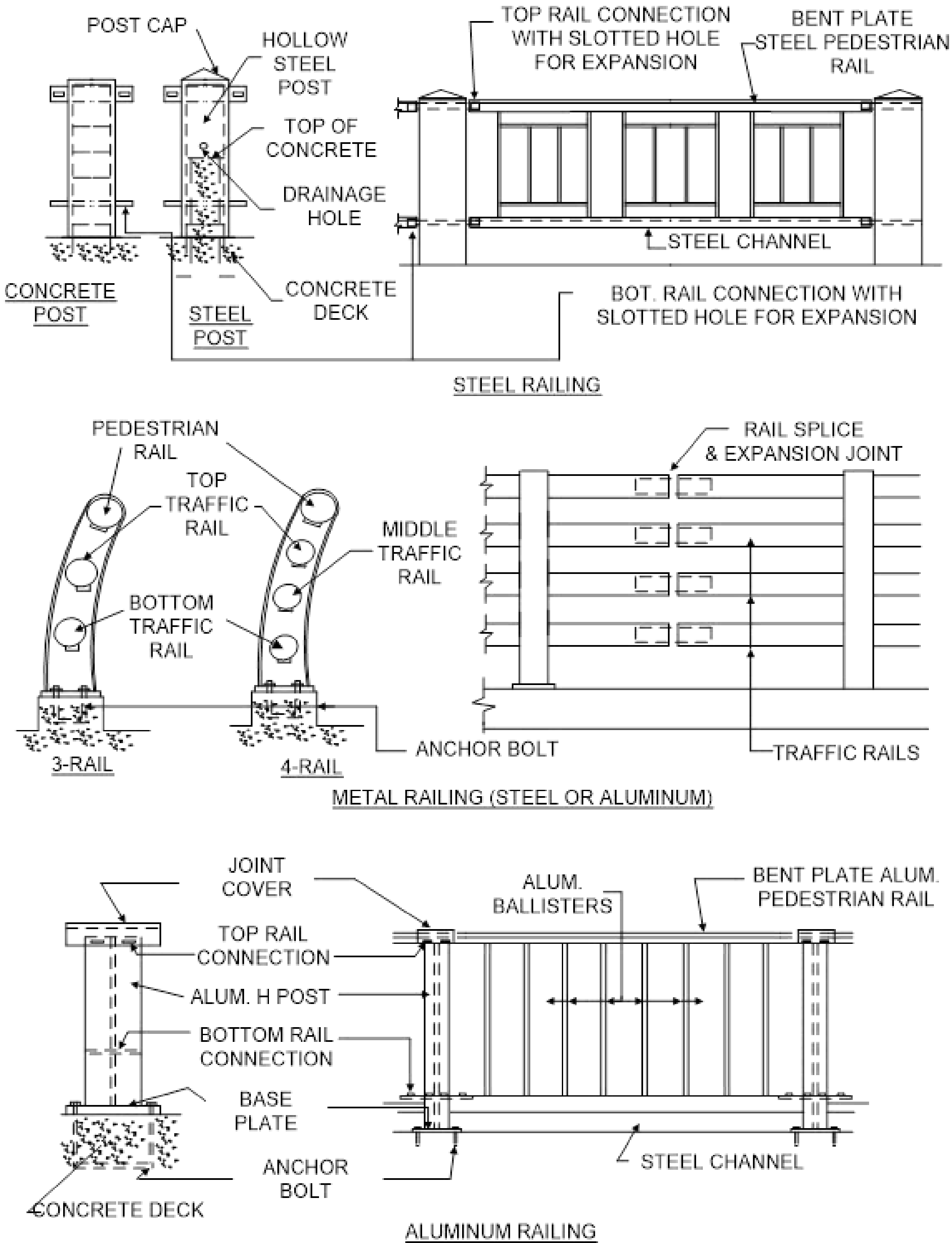


Figure 1.8.1.2 Railing System (cont.)

PART 1 – TECHNICAL INFORMATION

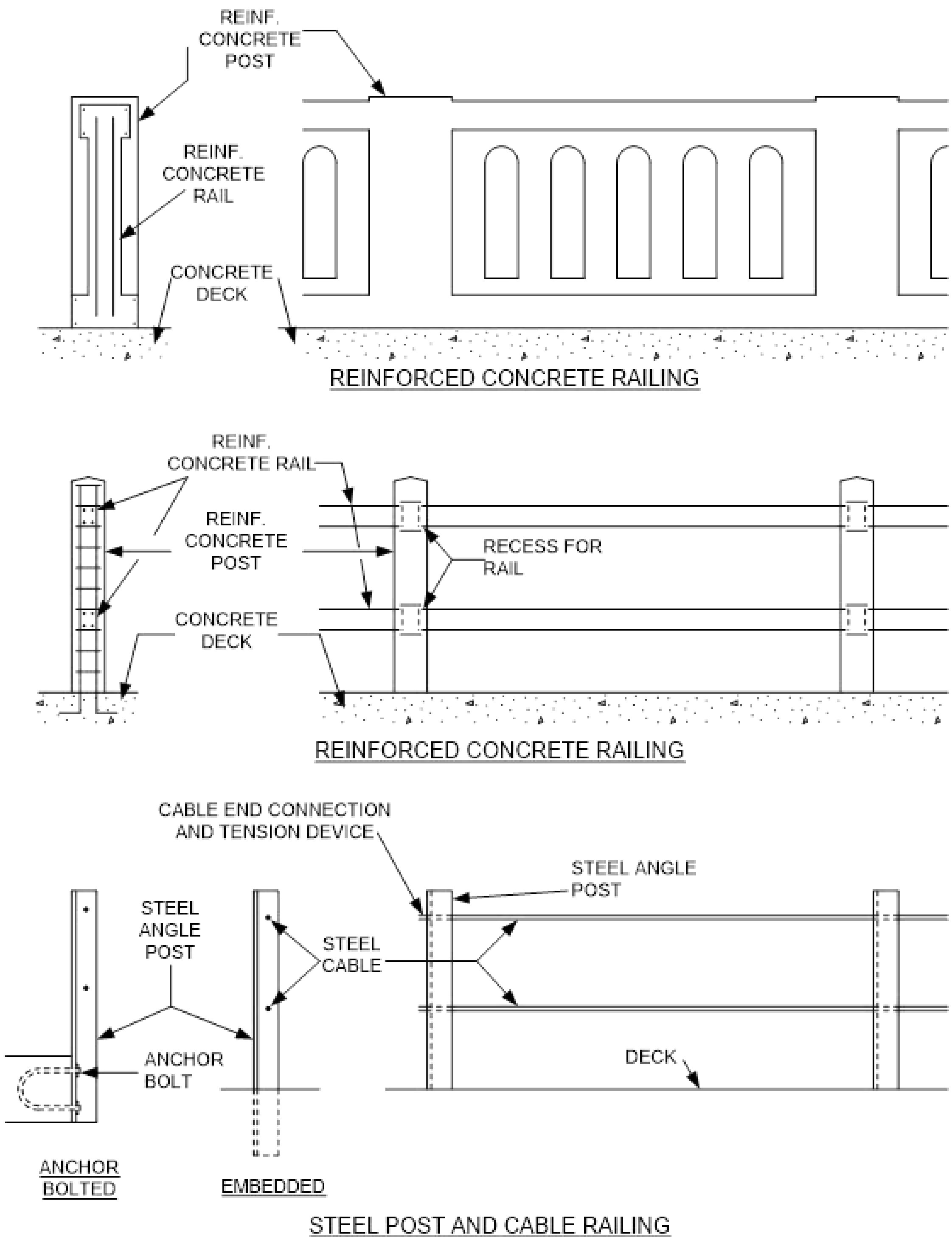
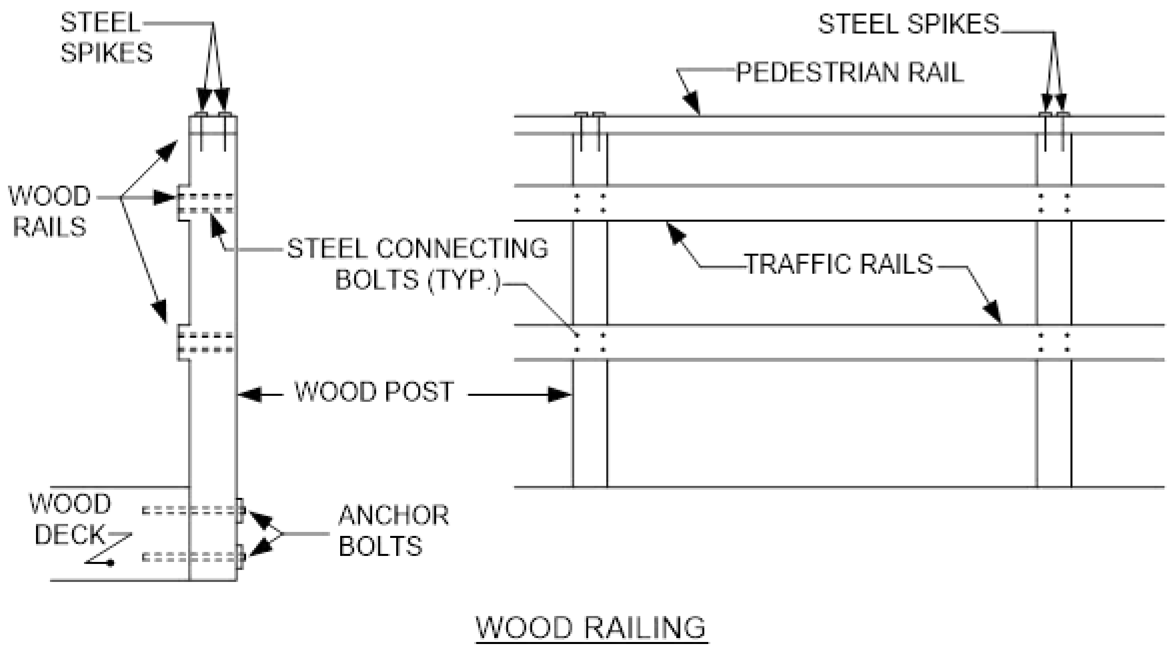


Figure 1.8.1.3 Railing Systems (cont. 2)

PART 1 – TECHNICAL INFORMATION



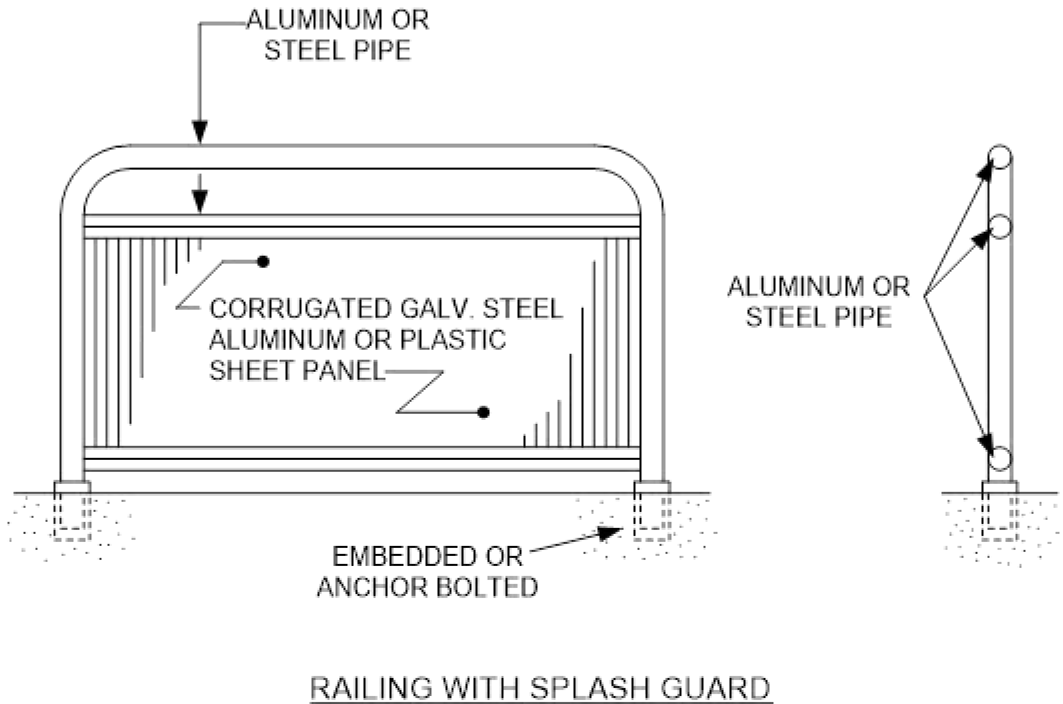


Figure 1.8.1.4 Railing Systems (cont. 3)

PART 1 – TECHNICAL INFORMATION

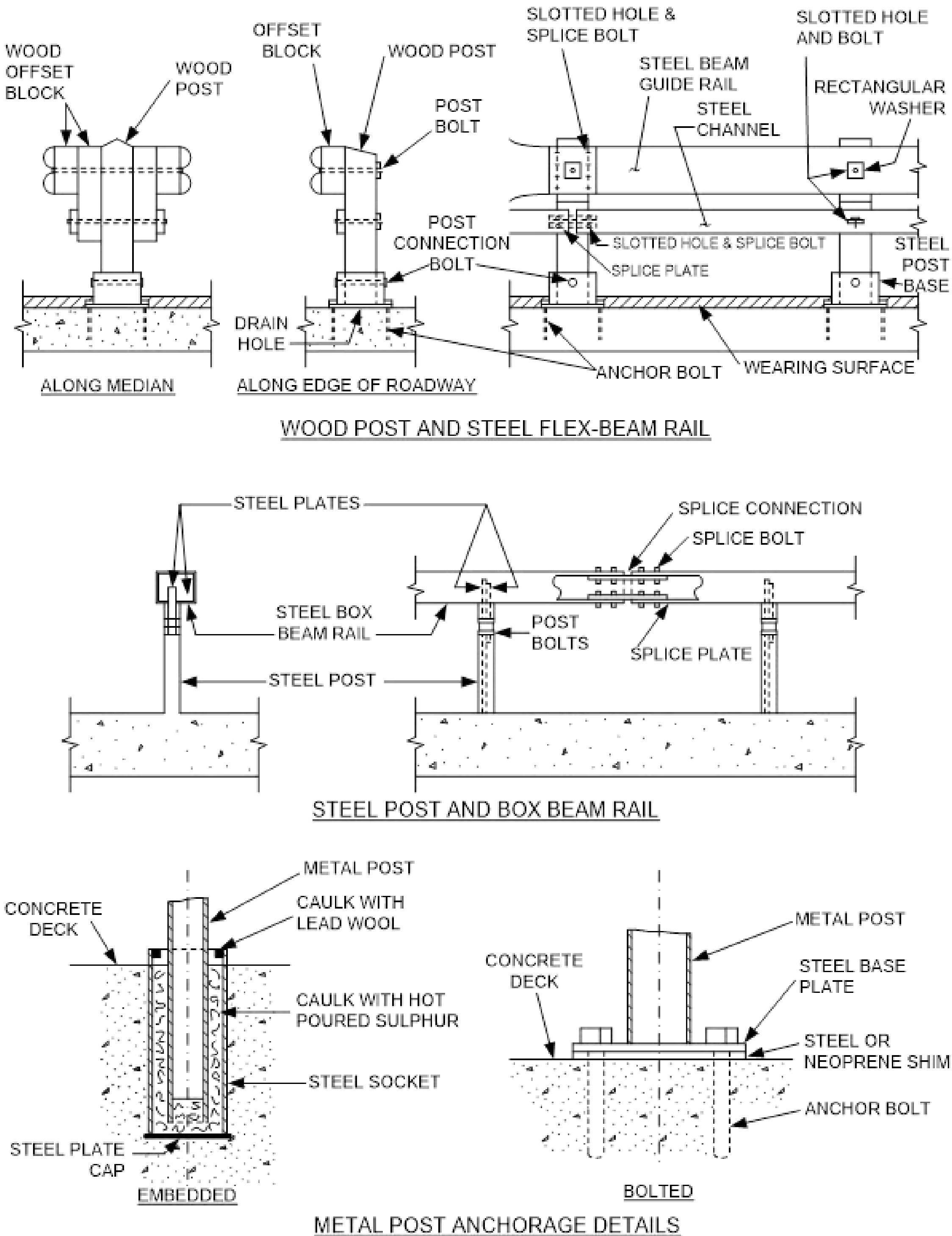
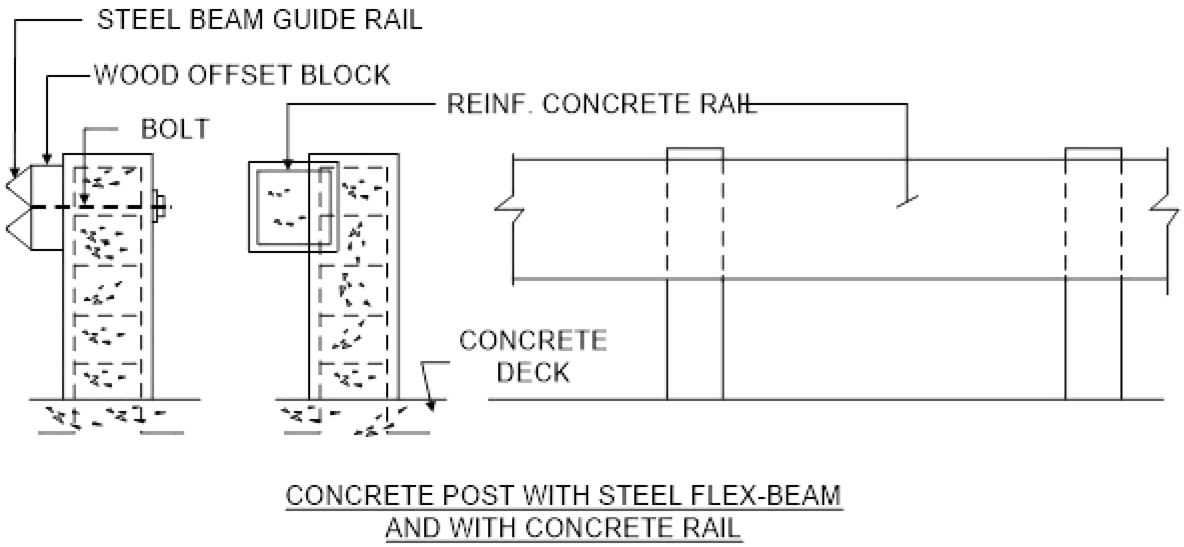


Figure 1.8.1.5 Railing System (cont. 4)

PART 1 – TECHNICAL INFORMATION



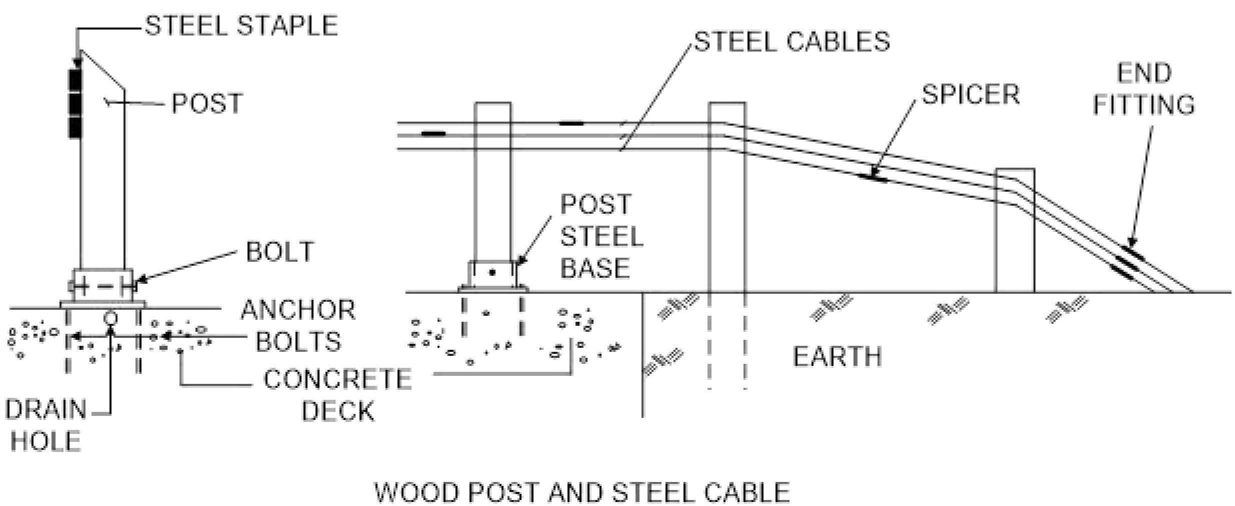


Figure 1.8.1.6 Railing System (cont. 5)

PART 1 – TECHNICAL INFORMATION

1.9 STRUCTURAL STEEL COATINGS

1.9.1 Structural Steel Coatings

Structural steel coatings are to be considered as auxiliary components. The following coatings and coating systems have been used on provincial steel structures (References 1 to 5).

(a) 3 Coat Alkyd System (**discontinued**)

This system was used on most coated steel bridges until about 1974 when it was discontinued. It consisted of:

- Red lead primer.
- Light grey second coat.
- Green top coat.

(b) Inorganic-Zinc/Vinyl System (**discontinued**)

This system has been used since about 1982 on a number of coated steel bridges. It consists of:

- reddish grey to greenish grey inorganic zinc primer;
- reduced vinyl wash second coat or proprietary tie coat, in white, green or grey;
- green high build vinyl third coat;
- high build vinyl topcoat, usually grey in colour, sometimes green.

(c) Epoxy-Zinc/Vinyl System (**discontinued**)

This system was used on coated steel bridges starting in 1987. It consists of:

- green or reddish grey organic zinc primer;
- high build vinyl second coat, in green or light grey;
- high build vinyl top coat, grey in colour.

(d) Aluminum-Filled Epoxymastic System

This system has been used since about 1982 on a number of coated steel bridges. It has also been used in selected locations on atmospheric corrosion resistant (weathering) steel, under expansion joints. It was discontinued in 1988. It consists of:

- two coats of aluminum coloured epoxy mastic

(e) Inorganic-Zinc/Epoxy/Urethane System

This low VOC system has been used on coated steel bridges since 1996. It consists of:

- reddish grey to greenish grey inorganic zinc primer;

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- an epoxy second coat, green or white;
- urethane top coat, grey in colour.

(f) Epoxy-Zinc/Epoxy/Urethane System

This low VOC system will be used on coated steel bridges starting in 1990. It consists of:

- green or reddish grey organic zinc primer;
- an epoxy second coat, in green or white;
- urethane top coat, grey in colour.

(g) Inorganic Zinc/Acrylic/Acrylic

This system is one of the low VOC systems that is in the DSM list for coating structural steel. It has only been used on a few bridges. It consists of:

- greenish-grey inorganic zinc primer;
- buff acrylic mid coat;
- grey acrylic topcoat.

(h) Epoxy-Zinc/Acrylic/Acrylic

This system is one of the low VOC systems that is in the DSM list for coating structural steel. It has only been used on a few bridges. It consists of:

- greenish grey organic (epoxy) zinc primer;
- buff acrylic mid coat;
- grey acrylic topcoat.

(i) High Build Alkyd System

This system was used on most coated steel bridges from about 1974 to 1985. Its use has virtually been discontinued. It consists of:

- yellow zinc chromate primer, one or two coats;
- green high build alkyd top coat (for handrails); or
- grey high build alkyd topcoat (for other steelwork).

(j) Hot Dip Galvanizing

Galvanizing has been used since about 1970 on Bailey bridges (TMB), some steel girders, various steel components and handrails. It consists of zinc applied to steel in a variety of methods and has a fairly smooth, large grain, shiny to semi-dull surface appearance.

(k) Metallizing

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Metallizing has been used since about 1970 on Bailey bridges (TMB), some steel girders, various steel components and on handrails. It consists of a sprayed coating of zinc or zinc/aluminum and has a coarse or gritty surface appearance resembling sandpaper. It has also been used to recoat the girders of one bridge.

(l) Coal Tar Epoxy

This system has been used in the past on the inside of some box girders. It is black or dark brown in colour.

(m) Coal Tar for Piles

This system has been used in the past on the inaccessible areas of steel behind abutment diaphragms and on steel piles. It is black in colour.

1.9.1.1 Material Defects of Steel Coatings

Material defects are as described in Part 2, Section 2.5.5.

1.9.1.2 Performance Defects of Steel Coatings

The performance of coatings is based upon the ability of the coating to protect the component against deterioration resulting from direct exposure to elements in the environment, such as moisture, de-icing salts, and airborne abrasives, pollutants and contaminants.

This degree of protection may be provided by a less than desirable material condition of the coating; however, increasing material defects and deterioration will ultimately result in loss of protection provided by the coating or coating system.

The rate of deterioration of the coating depends on the degree of exposure of the component to the destructive elements.

In addition, where identical exposure conditions prevail, the following features can also affect the rate of deterioration of the coating, namely:

- horizontal surfaces usually deteriorate at a faster rate than vertical surfaces;
- outside corners and edges of components usually exhibit greater deterioration, as coating thickness is often less at these locations;
- poor surface preparation or inadequate coating thickness, usually due to poor workmanship or difficult accessibility of the surface.
- the amount of time the steel is damp and the degree to which the component is ventilated also has an effect.

1.9.2 References

1. Technical Data on Approved Coating Systems Designated Sources List DS: 113, MI-72. Materials Information, Engineering Materials Office, M.T.C.
2. MTO Designated Sources Lists 9.20

3. SSPC Painting Manual, Volume 2, Good Painting Practice, SSPC the Society for Protective Coatings.
4. SSPC Painting Manual, Volume 2, Systems and Specifications, SSPC the Society for Protective Coatings.
5. Ridley, Grant, "Laboratory Evaluation of Low VOC Coating Systems for Abrasive Blast Cleaned Steel", Nov. 1993, Internal Report, Ministry of Transportation, Chemical Section, Material Engineering and Research Office, Building C, 1201 Wilson Avenue, Downsview.
6. Ministry of Transportation Structural Steel Coating Manual, 2004.

1.10 SIGNS

1.10.1 Signs

1.10.1.1Bridge Mounted Sign Supports

Bridge Mounted Sign Supports described in the Ontario Sign Support Manual and are categorized into Type I, Type II, Type III, and Type IV. Their use on MTO structures has been discouraged and have been avoided where a ground mounted sign or another stand alone Overhead Sign Supports can be used. As a result of this the MTO inventory of these types of sign supports have decreased. However, for the purposes of OSIM inspections, Type 1 Bridge Mounted Sign Supports with sign boards with an area less than 2 m^2 should be inspected with the bridge and does not require a separate inspection or a separate Site Number (MTO asset number). The inspector shall consult the Ontario Sign Support Inspection Manual (OSSIM) and the Ontario Sign Support Manual when inspecting these components.

Type I (Type II, Type III, and Type IV Bridge Mounted Signs shall have their own separate inspection and Site Number and be inspected in accordance with the OSSIM. These inspections should ideally be conducted at the same time as the bridge inspection

Bridge Mounted Sign Support components can be used by other jurisdictions that do not perform separate inspections of their larger bridge mounted sign supports.

The signs most commonly used to indicate restrictions at structures are described below and shown in Figure 1.10.2.1 to Figure 1.10.2.3. These types of signs should be considered as attachments to the structure. Where signs are available in two sizes, the oversize signs are used on Provincial Highways. They may also be used on other equally important high-speed roadways or at locations where greater visibility or impact of the sign is required. Signs are considered Auxiliary Components.

Note that this section does not refer to Bridge Mounted Signs as described in the Overhead Sign Support Manual, Please refer to 1.11.4 for information on Bridge Mounted Signs.

A full description of the following signs and their application is contained in the Highway Traffic Act..

a) Narrow Structure Signs

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The Narrow Structure sign is used to indicate a bridge culvert, subway, overpass, or similar structure having a clear roadway width of 5 to 6 m inclusive or any structure with a roadway clearance less than the width of the approach pavement.

The Narrow Structure sign is erected not less than 150 m nor more than 250 m in advance of the structure.

It is available in two sizes.

Hazard Markers shall be used with the narrow structure signs.

b) One Lane Signs

Where the structure has a clear roadway width of less than 5 m, thereby permitting only a single lane of traffic, a tab sign reading "One Lane" is added immediately below the Narrow Structure sign.

The "One Lane" tab sign may also be used where the structure roadway width is less than 5.5 m when commercial vehicles constitute a significant proportion of the traffic using the structure or when the alignment approaching the structure is poor.

c) One lane Only When Used by Trucks Signs

"One Lane Only When Used by Trucks" sign is used to supplement the Narrow Structure symbol sign where the shape of the subway or the curvature of the road requires trucks to swing to the centre of the roadway in order to pass through. It may also be used where the structure roadway width is less than 5.5 m when commercial vehicles constitute a significant proportion of the traffic using the structure, or where the alignment approaching the structure is poor.

It is erected approximately 50 m beyond the Narrow Structure Symbol Sign.

d) Hazard Marker Signs

Hazard Marker signs are used to mark structure limits when they are within 2 m of the edge of the roadway in conjunction with the Narrow Structure sign.

Left or right hazard markers are erected with the stripes sloping at an angle of 45 degrees down towards the edge of the travelled portion of the roadway.

The right marker is always used to the right of traffic and left marker to the left.

Left and right hazard marker is used where traffic may pass on both sides of an obstruction.

e) Low Clearance Signs

The Low Clearance signs, indicating low overhead clearance and showing the exact amount of clearance at low bridges, underpasses, and other structures, are used at all points where clearance from the roadway to the low point of the structure is less than 4.5 m.

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The Clearance sign is erected, if possible, on the structure just above the opening and over the centre of the roadway unless the clearance across the structure varies between the centreline and the curb or edge of pavement, in which case a second sign is erected to indicate the lesser clearance. Where there is a difference in clearance across the structure and the roadway is considered “one lane” when used by trucks, there shall be three signs posted: at the centreline and each edge of pavement.

The Advance clearance sign is located not less than 100 m nor more than 250 m in advance of the subway. The advance clearance sign is available in two sizes.

f) Maximum Weight Signs

Single maximum weight signs and multiple maximum weight signs are erected to limit the gross weight on bridges under the authority of an Ontario Regulation or a Municipal Bylaw approved by the Ministry as per the Highway Traffic Act and Directive B-43, Maximum Weight on Bridges Sign.

Regulatory maximum weight signs have black legend, symbols, and border on white reflective background.

Advisory maximum weight signs have black legend, symbols, and border on yellow reflective background.

g) Others

There may also be other signs at structures, such as, speed restriction, slippery when wet, bailey bridge ahead, marine warning lights and signs.

1.10.1.2 Defects of Signs

The following are some of the typical defects in signs:

- loose, broken or missing components;
- illegible;
- not located according to standards;
- gives misleading, wrong or inaccurate information;
- not a standard sign.

1.10.2 References

1. Manual of Uniform Traffic Control Devices for Canada, Sixth Edition, TAC, 2021
2. Highway Traffic Act, RSO 1990. Website ontario.ca/laws
3. Ministry Directive B-43 – Maximum Weight on Bridges Sign

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(75 x 75) CM or (90 x 90) CM
(A) NARROW STRUCTURE SIGN

(B) ONE LANE SIGN

(90 x 90) CM
(C) ONE LANE ONLY WHEN USED BY TRUCKS SIGN

Figure 1.10.2.1 Signs

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(d) Hazard Marker Signs

Figure 1.10.2.2 Signs (cont.)

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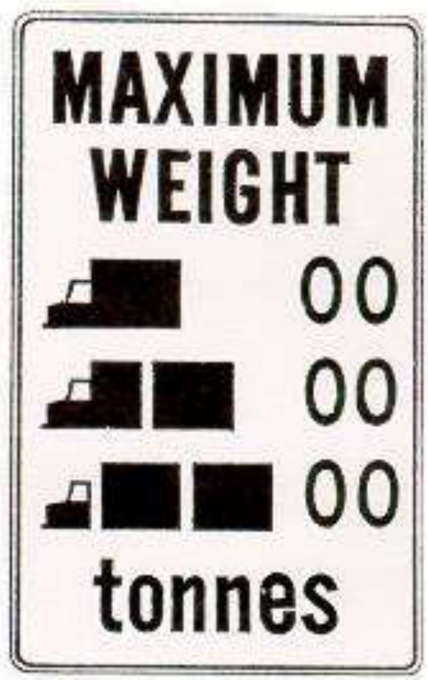
(60 x 90) CM
CLEARANCE SIGN

(60 x 60) CM OR (90 x 90) CM
ADVANCE CLEARANCE SIGN

(E) LOW CLEARANCE SIGNS

SINGLE POSTING SIGN



MULTIPLE POSTING SIGN

(F) MAXIMUM WEIGHT SIGNS

Figure 1.10.2.3 Signs (cont. 2)

PART 1 – TECHNICAL INFORMATION

1.11 ATTACHMENTS

1.11.1 General

The owner should be contacted to determine which attachments to the structure need to be inspected as part of the structure inspection. All attachments should be considered Auxiliary Components.

1.11.2 Utilities

Utilities most commonly hung from, attached to, or installed in the structure are:

- Water mains
- Gas mains
- Bell ducts
- Hydro lines

A variety of attachment methods are used to install these utilities on the structure.

1.11.3 Electrical

This category is not used by the Ontario Ministry of Transportation (MTO) since MTO Maintenance Contractors inspect electrical installations in accordance with the Electrical Engineering Manual, Volume 2 – Electrical Maintenance.

This category can be used by jurisdictions that do not perform separate inspections of their electrical attachments to their structures. Electrical attachments to bridges generally are:

- Light Poles
- Underpass Lighting
- Cathodic Protection Conduits

A variety of attachment methods are used to install these accessories on the structure.

1.11.4 Bridge Mounted Sign Supports

Bridge Mounted Sign Supports described in the Ontario Sign Support Manual and are categorized into Type I, Type II, Type III, and Type IV. Their use on MTO structures has been discouraged and have been avoided where a ground mounted sign or another stand alone Overhead Sign Supports can be used. As a result of this the MTO inventory of these types of sign supports have decreased. However, for the purposes of OSIM inspections, Type I Bridge Mounted Sign Supports with sign boards with an area less than 2 m^2 should be inspected with the bridge and does not require a separate inspection or a separate Site Number (MTO asset number). The inspector shall consult the Ontario Sign Support Inspection Manual (OSSIM) and the Ontario Sign Support Manual when inspecting these components.

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Type II, Type III, and Type IV Bridge Mounted Signs shall have their own separate inspection and Site Number and be inspected in accordance with the OSSIM.

Bridge Mounted Sign Support components can be used by other jurisdictions that do not perform separate inspections of their larger bridge mounted sign supports.

1.11.5 Noise Barriers

Noise barriers on bridges typically have posts anchored to the barrier wall with panels between the posts.

1.11.6 Other Attachments

Other attachments can include:

- Banner mounting hardware on bridges,
- Fixed Automated Spray Technology (FAST)for de-icing
- Light poles on structure (if cursory inspection and others are performing detailed inspection on pole).

1.11.7 Defects Of Attachments

The following are some typical defects of attachments:

- loose, broken or missing components;
- cracks in anchorages, connections or clamps;
- corrosion (i.e., on clamps, posts or steel noise barriers);
- concrete deterioration such as scaling, spalling, etc. (i.e., on noise barriers);
- mechanical damage;
- other visually apparent defects which may cause the attachment(s) to fail resulting in loss of support.

experience

PART 2 – DETAILED VISUAL INSPECTION

2.1 OVERVIEW OF VISUAL INSPECTIONS

2.1.1 Qualifications Of Inspectors

2.1.1.1 Minimum Qualifications for Inspectors of Non-MTO Structures

Detailed visual inspections of structures should be carried out by:

- Professional Engineers with a background in inspection, design and construction of bridges or,
- Trained bridge inspectors reporting to, or under the supervision of a Professional Engineer.

2.1.1.2 Qualifications Required for Inspections of MTO Structures

Inspection of Bridges and Tunnels:

Lead Inspector (on site):

1. Professional Engineer, with minimum 3 years of bridge inspection experience or Certified Engineering Technologist or Engineer-in-Training with 100 previous OSIM inspections.

2. Attended the most recent MTO Bridge Inspection Workshop.

3. Inspector must complete and pass the MTO's Bridge Inspection Consistency Exercises.

Supervising Engineer:

1. Professional Engineer licenced for 5 years with a minimum of 5 years background in inspection, design, and construction of bridges.

2. Completed a minimum of 3 MTO bridge projects (design or OSIM inspection assignment).

Inspection of Culverts and Retaining Walls

Lead Inspector (on site):

1. Professional Engineer with a minimum of 20 previous OSIM inspections or a Certified Engineering Technologist or Engineer-in-Training with 100 previous OSIM inspections.

2. Attended the most recent MTO Bridge Inspection Workshop

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3. Inspector must complete and pass the MTO's Bridge Inspection Consistency Exercise.

Supervising Engineer:

1. Professional Engineer licenced for 5 years with a minimum of 5 years background in inspection, design, and construction of bridges.

2. Completed a minimum of 3 MTO bridge projects (design or OSIM inspection assignment).

2.1.2 Responsibilities Of Inspectors

The main responsibilities of inspectors are:

Table 2.1.1: Responsibilities of Inspectors

Responsibilities	Section Reference
Inspect all elements that comprise the structure	2.2, 2.4,
Record all areas of material defects for each element, and categorise them under a defined Condition State	2.5
Identify suspected performance deficiencies	2.6
Note areas of the structure where maintenance is required	2.7
Make recommendations for urgent repairs of the structure	2.8
Indicate the suggested time frame or urgency of the proposed work	2.7, 2.8
Identify additional detailed investigations that are required	2.8
Ensure that appropriate actions are taken or initiated to address safety concerns	1.1.2.2, 2.1.5.3

2.1.3 Safety Requirements

Inspectors shall take proper safety precautions and comply with the appropriate safety and traffic control legislation, regulations, manuals, and guidelines such as the Occupational Health and Safety Act, The Manual of Uniform Traffic Control Devices, Safety Practices for Structure Inspections, etc. The specific requirements of these safety and traffic control guidelines and procedures are not covered in this manual.

2.1.4 Inspection Equipment

2.1.4.1 Standard Equipment Carried by Inspectors

All inspection personnel should be equipped with and be thoroughly familiar with the use of the following equipment:

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- Binoculars
- Camera
- Chalk, markers, and paint markers
- Inspection forms and clip boards
- Flashlight (focussing type)
- Chain (2 m)
- Light chipping hammer
- Measuring tape (3 m)
- Measuring tape (30 m)
- "Workers ahead" signs
- Mirror on a swivel head with an extension arm
- Plumb bob
- Pocket knife or multi-tool
- Range poles
- Safety belts and lanyard
- Boots, hat, gloves, vest
- Flotation vest
- Safety cones and flashing light
- Scraper
- Screwdriver (large)
- Sounding line (lead line)
- Straight edge (1 m)
- Air thermometers
- Wire brush
- Re-chargeable drill with bits
- Grinder
- Wood borer and treated plugs
- Eye level and hand level
- Stringline
- Drone
- Other equipment as required

2.1.4.2 Use of Drones to Supplement Inspections

Drones (Unmanned Aircraft Systems) may be used as supplemental tools to enhance visual data collection during OSIM inspections. Drone inspections do not replace Regular OSIM or Enhanced inspections. Their use is limited to supporting difficult-to-access areas where drone imagery can improve efficiency and safety.

All drone operations must comply with Transport Canada's Canadian Aviation Regulations, Part IX (SOR/96-433). Pilots must hold all required certifications and shall not operate drones on Ministry property without the necessary regulatory knowledge and approvals.

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Appropriate Use of Drones

Use of drones is situational, depending on structure type, site conditions, and drone capabilities. Drone inspections may be used only when they can safely and effectively support the inspection tasks assigned.

When used appropriately, drones can:

- Reduce reliance on access equipment
- Decrease time spent working near live traffic
- Improve documentation of hard-to-reach locations

These benefits apply only when drone capabilities align with specific inspection needs.

Ideal Structures for Drone Use

- Water crossings
- Large culverts with sufficient clearance
- Tall structures not directly over live traffic

Non-Ideal Structures

- Underpasses with live traffic and no traffic control
- Low-clearance structures
- Railway structures without appropriate approvals

Most drones cannot perform tasks requiring tactile assessment, sounding, or measurement of defect dimensions; these must be completed through traditional inspection methods. Where specialized drone technologies are proposed for advanced inspection tasks, they will be evaluated case-by-case at the Owner's Engineer's discretion. Additional restrictions may apply.

Drone use on non-ideal structures is generally discouraged. If required under special circumstances, the Engineer must review and approve their use, including any additional restrictions or traffic protection measures.

Drone Capabilities

At a minimum, drones used for OSIM inspections must capture high-resolution images ($\geqslant$ 3840 × 2160, 4K UHD) that clearly represent structural elements and defects. Beneficial features include:

- Obstacle avoidance
- GPS navigation
- Extended battery life
- Adjustable altitude limits
- High-zoom camera
- Supplemental lighting

The Engineer will determine whether to use video, photographs, or a combination to supplement the inspection.

- Photographs may be used for structures in good condition with few defects.
- Video or hybrid methods are preferred for structures with numerous or severe defects.

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High-resolution video provides comprehensive data but requires greater battery capacity, post-processing effort, and storage.

Traffic Control Requirements
Drones must adhere to the traffic control plan as though they were inspectors. A drone must not enter any area that an inspector would be prohibited from entering under the same plan. *Example: The drone can cross a road only if the roadway is designated as an intermittent work area in the traffic control plan.*

Inspection Tasks Appropriate for Drone Use
Drones may be used for visual documentation of difficult-to-access components on suitable structures, including:

- Soffits
- Girders, diaphragms, and bracing
- Piers and pier caps
- Exterior barrier walls and fascia
- Bearings

Drone Best Practices for Structural Inspections

The following should be considered best practices and should be adhered to when using drones to aid OSIM inspections,

- Flying directly over structures with live traffic present should be avoided when possible. Attempt to collect data from a safe position off to the side of the structure.

- Avoid crossing directly over the highway with the drone when traffic is present whenever possible. If necessary to cross the roadway with the drone, attempt the following,
  - Cross the road at the highest altitude above ground level as practical as per the regulations. This will reduce driver distraction.
  - Do not linger over the roadway.
  - Attempt the crossing when there is a break if traffic.
  - Attempt to avoid a vehicle(s) passing directly beneath the drone during the crossing.

- Never operate a drone under bridge decks with live traffic lanes present below or nearby without an approved traffic control plan.

- Drones shall not take off or land within 5 metres of the outer edge of live freeway traffic lanes, and 4 metres from highway traffic lanes. Drones are more vulnerable to collisions when landing and launching and can be susceptible to traffic-induced wind gusts. Conducting takeoff and landing procedures at safe distance eliminates the risk of unstable air from traffic and helps reduce driver distraction.

- Drones shall not take off or land within highway or freeway medians, as this poses a driver distraction and restricts safe emergency-landing options.