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Chapter 3
Basic Bridge Terminology

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Topic 3.1 Basic Bridge Terminology

3.1.1 Introduction

It is important to be familiar with the terminology and elementary theory of bridge mechanics and materials. This topic presents the terminology needed by inspectors to properly identify and describe the individual elements that comprise a bridge. First the major components of a bridge are introduced. Then the basic member shapes and connections of the bridge are presented. Finally, the purpose and function of the major bridge components are described in detail.

3.1.2 NBIS Structure Length

According to the *FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, the structure length is measured in accordance with Item 49 as shown on Figure 3.1.1. The structure length is the length of the roadway that is supported by the bridge structure. To determine the length, measure back to back of back-walls of abutments or from paving notch to paving notch. If the location of the backs of backwalls cannot be exactly determined, inspectors can then measure the distance between the paving notches to determine structure length.

To measure the length of culverts, measure along the center line of the roadway regardless of their depth below grade. The measurements will be between the inside faces of the exterior walls. Tunnels should be measured along the center of the roadway.

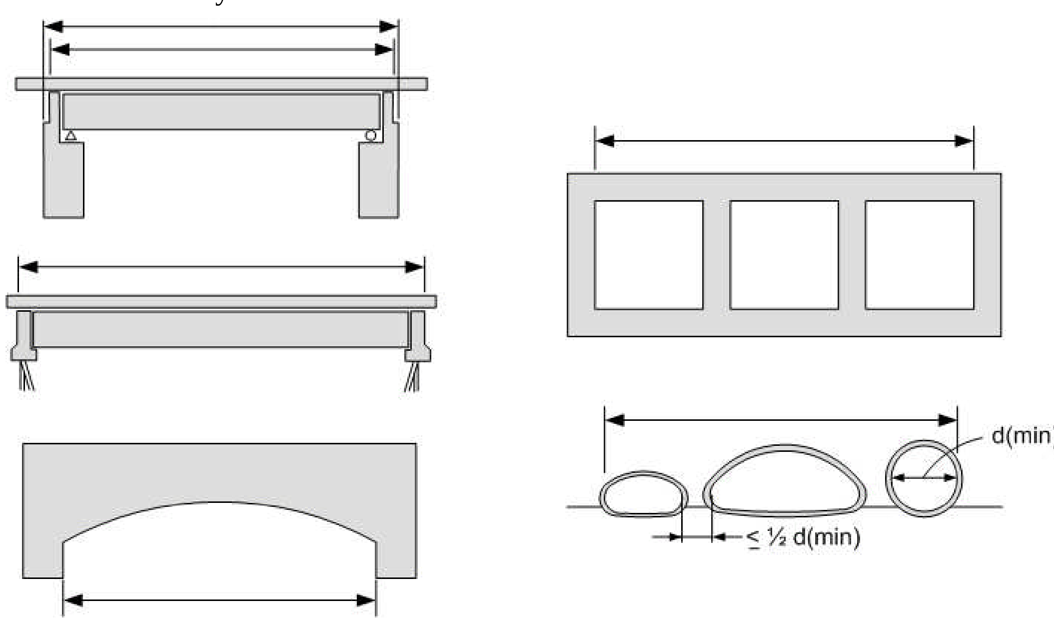


Figure 3.1.1 NBIS Structure Length

3.1.3 NBIS Bridge Length

The *FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* also states, in accordance with Item 112 – NBIS Bridge Length, that the minimum length for a structure to be considered a bridge for National Bridge Inspection Standards purposes, is to be 20 feet (see Figure 3.1.2).

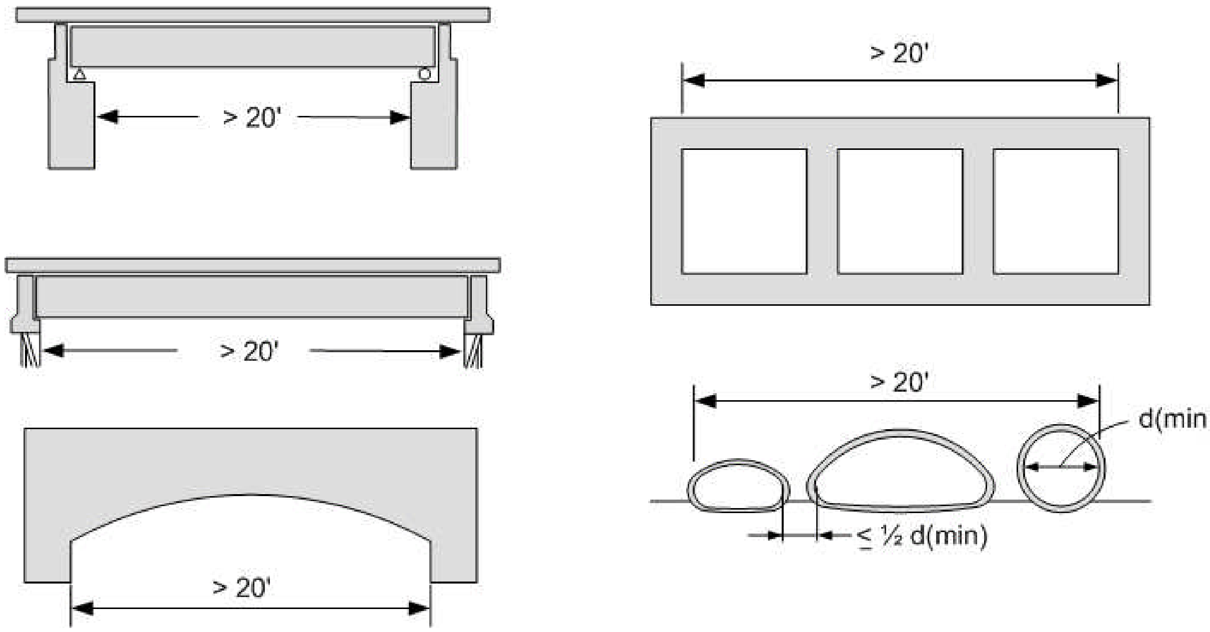


Figure 3.1.2 NBIS Bridge Length (Coding Guide Item 112)

23 CFR Part 650.305 Definitions gives the definition of a bridge as it applies to the NBIS regulations: A bridge is a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.

3.1.4 Major Bridge Components

A thorough and complete bridge inspection is dependent upon the bridge inspector's ability to identify and understand the function of the major bridge components and their elements. Most bridges can be divided into three basic parts or components (see Figure 3.1.3):

- Deck
- Superstructure
- Substructure

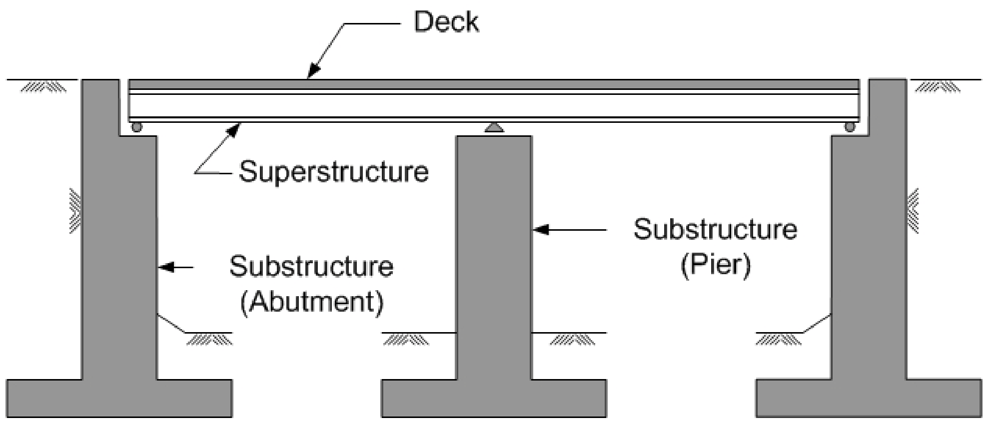


Figure 3.1.3 Major Bridge Components

3.1.5 Basic Member Shapes

The ability to recognize and identify basic member shapes requires an understanding of the timber, concrete, and steel shapes used in the construction of bridges.

Every bridge member is designed to carry a unique combination of tension, compression, and shear. These are considered the three basic kinds of member stresses. Bending loads cause a combination of tension and compression in a member. Shear stresses are caused by transverse forces exerted on a member. As such, certain shapes and materials have distinct characteristics in resisting the applied loads. For a review of bridge loadings and member responses, see Topic 5.1.

Timber Shapes

Basic shapes, properties, gradings, deficiencies, protective systems, and examination of timber are covered in detail in Topic 6.1.

Timber members are found in a variety of shapes (see Figure 3.1.4). The sizes of timber members are generally given in nominal dimensions (such as in Figures 3.1.4 and 3.1.5). However, sawn timber members are generally seasoned and surfaced from the rough sawn condition, making the actual dimension about 1/2 to 3/4 inches less than the nominal dimension.

The physical properties of timber enable it to resist both tensile and compressive stresses. Therefore, it can function as an axially-loaded or bending member. Timber bridge members are made into three basic shapes:

- Round – piles, columns, posts
- Rectangular – planks, beams, columns, piles
- Built-up shapes - beams

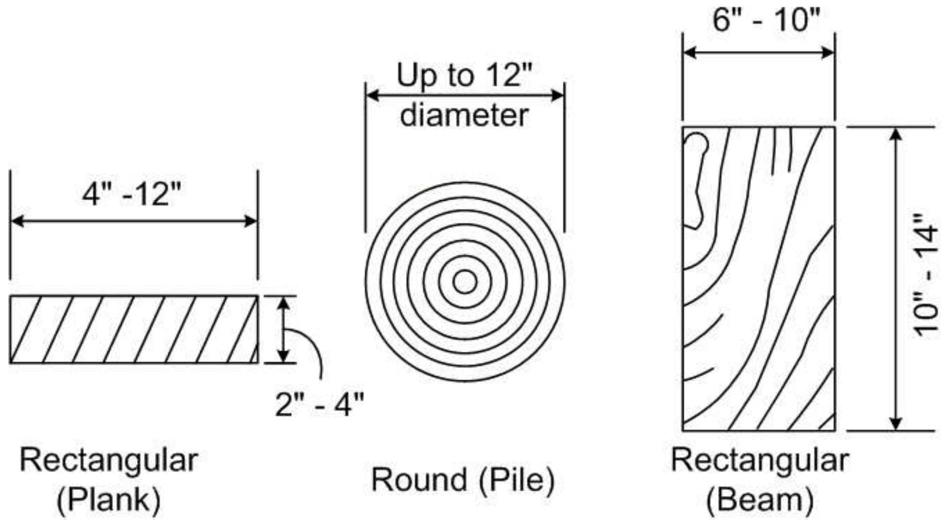


Figure 3.1.4 Timber Members

Planks

Planks are characterized by elongated, rectangular dimensions determined by the intended bridge use. Plank thickness is dependent upon the distance between the supporting points and the magnitude of the vehicle load. Common nominal or rough sawn dimensions for timber planks are 2 to 4 inches thick and 6 to 12 inches wide. Dressed lumber dimensions would be 1 ½ inches x 11 ¼ inches (see Figure 3.1.4).

Planks are most often used for bridge decks on bridges carrying light or infrequent truck traffic. Timber plank decks have been used for centuries. Timber planks are advantageous in that they are economical, lightweight, readily available, and easy to install.

Beams

Timber beams have more equal rectangular dimensions than do planks, and they are sometimes square. Common dimensions include 10 inch by 10 inch square timbers, and 6 inch by 14 inch rectangular timbers. Beams generally are installed with the larger dimension vertical.

As the differences in the common dimensions of planks and timber beams indicate, beams are larger and heavier than planks and can support heavier loads, as well as span greater distances. As such, timber beams are used in bridge superstructures and substructures to carry bending and axial loads.

Timbers can either be solid sawn or built-up glued-laminated (see Figure 3.1.5). Glued-laminated timbers are advantageous in that they can be fabricated from smaller, more readily available pieces. Glued lamination also allows larger rectangular members to be formed without the presence of natural deficiencies such as knots. Glued-laminated timbers are normally manufactured from well-seasoned wood and display very little shrinkage after they are fabricated.

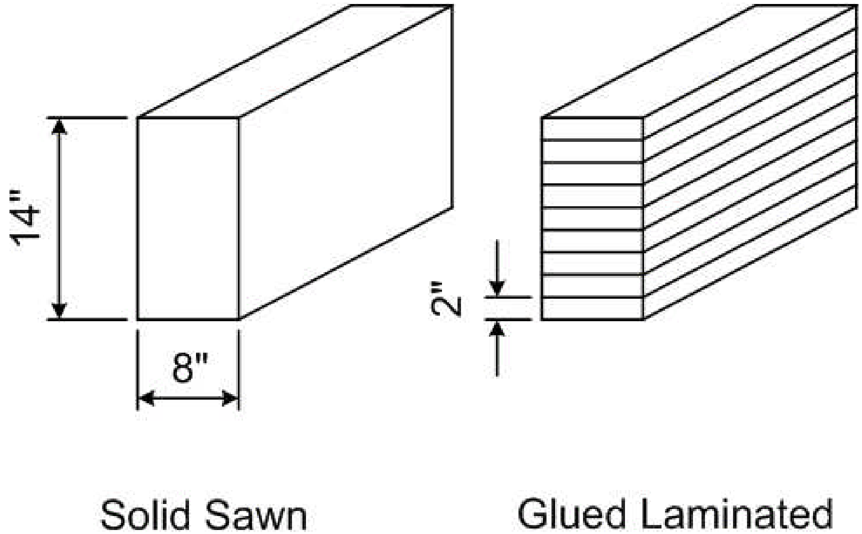


Figure 3.1.5 Timber Beams

Piles/Columns

Timber can also be used for piles or columns. Piles are normally round, slender columns that support the substructure footing or partially form the substructure. Piles may be partially above ground or completely buried.

Concrete Shapes

Basic ingredients, properties, reinforcement, deficiency, protective systems, and examination of concrete are covered in detail in Topic 6.2.

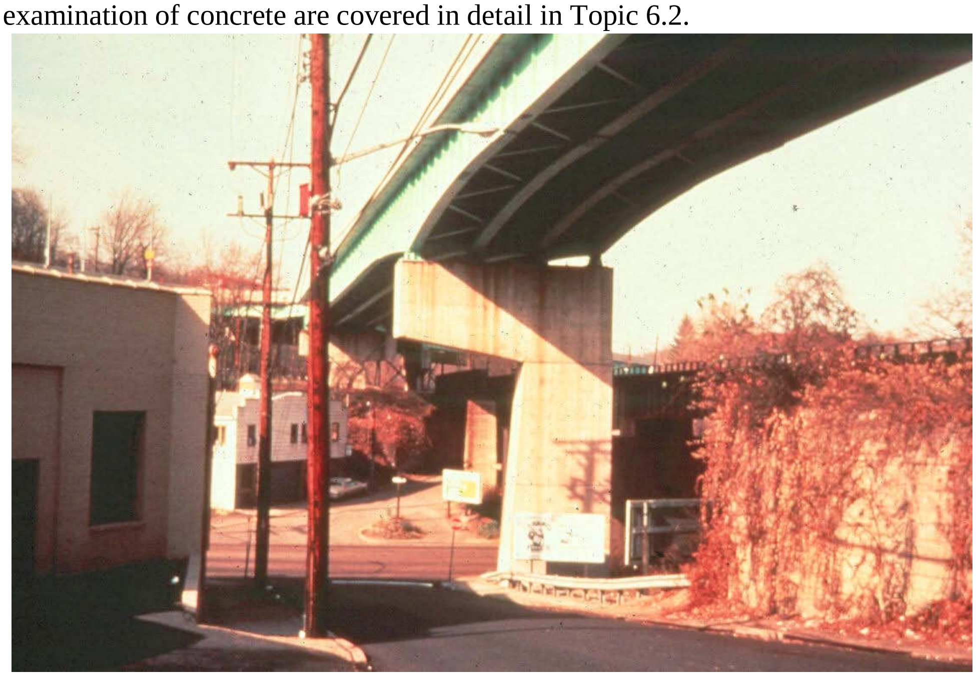


Figure 3.1.6 Unusual Concrete Shapes

Concrete is a unique material for bridge members because it can be formed into an infinite variety of shapes (see Figure 3.1.6). Concrete members are used to carry axial and bending loads. Since bending results in a combination of compressive and tensile stresses, concrete bending members are typically reinforced with either reinforcing steel bars (producing conventionally reinforced concrete) or with prestressing steel (producing prestressed concrete) in order to carry the tensile stresses in the member. Reinforcing steel is also added to increase the shear and torsion capacity of concrete members.

Cast-in-Place Flexural Shapes

The most common shapes of reinforced concrete members are (see Figure 3.1.7):

- Slabs/Decks
- Rectangular beams
- Tee beams
- Channel beams

Bridges utilizing these shapes and mild steel reinforcement have been constructed and were typically cast-in-place (CIP). Many of the designs are obsolete, but the structures remain in service. Concrete members of this type are used for short and medium span bridges.

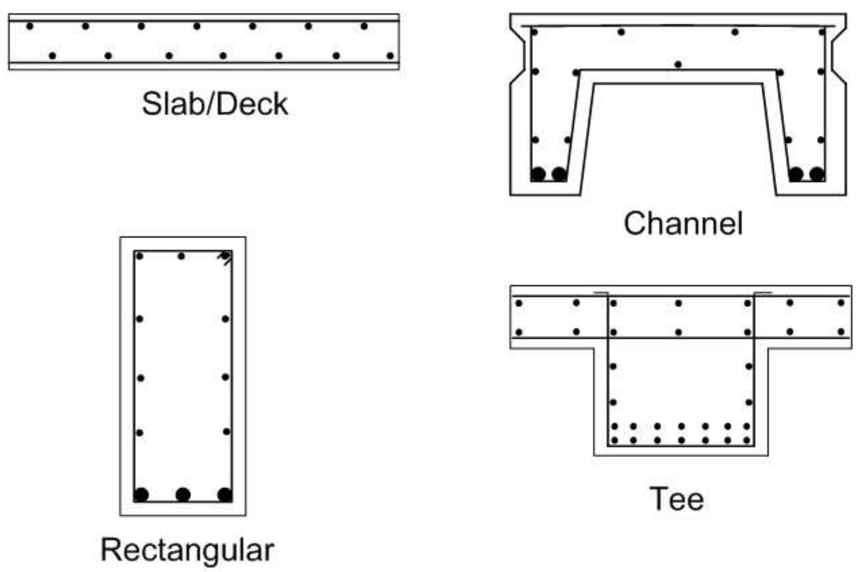


Figure 3.1.7 Reinforced Concrete Shapes

On concrete decks, the concrete spans the distance between superstructure members and is generally 7 to 9 inches thick. On slab bridges, the slab spans the distance between piers or abutments, forming an integral deck and superstructure. Slab bridge elements are usually 12 to 24 inches thick.

Rectangular beams are used for both superstructure and substructure bridge elements. Concrete pier caps are commonly rectangular beams which support the superstructure.

Tee beams are generally limited to superstructure elements. Distinguished by a "T" shape, tee beams combine the functions of a rectangular stem and flange to form an integral deck and superstructure.

Channel beams are generally limited to superstructure elements. This particular shape can be precast or cast-in-place. Channel beams are formed in the shape of a "C" and placed legs down when erected. They function as both superstructure and deck and are typically used for shorter span bridges.

Precast Flexural Shapes

The most common shapes of prestressed concrete members are (see Figure 3.1.8):

- I-beams
- Bulb-tees
- Voided or solid slabs
- Box beams
- Box girders

These shapes are used for superstructure members.

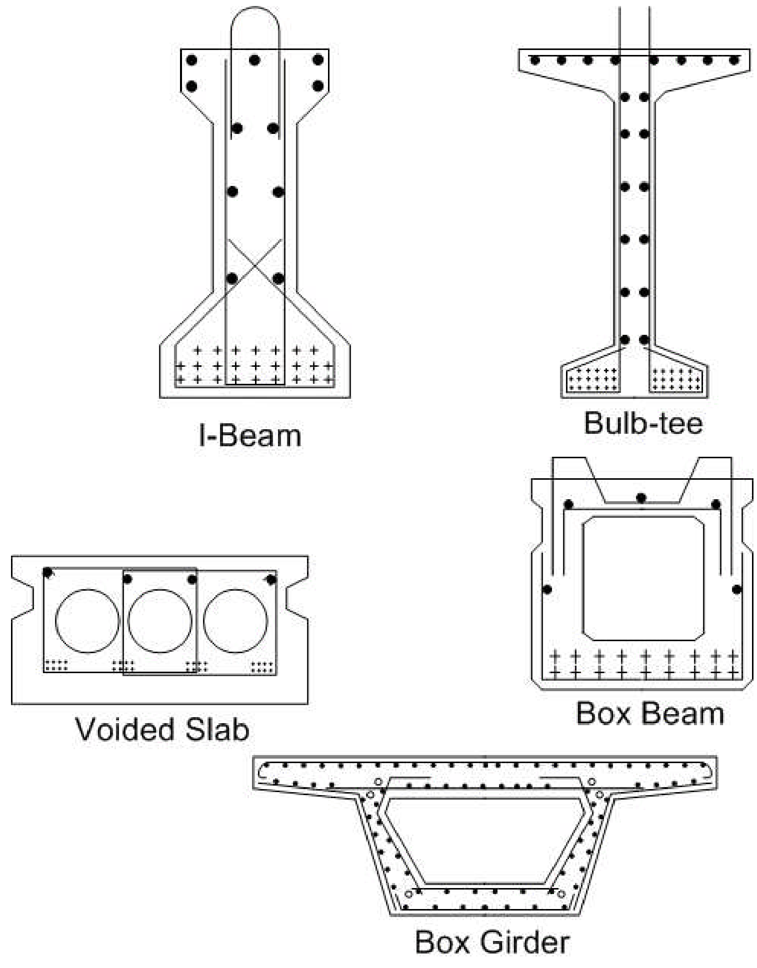


Figure 3.1.8 Prestressed Concrete Shapes

Prestressed concrete beams can be precast at a fabricator's plant using high compressive strength concrete. Increased material strengths, more efficient shapes, the prestress forces and closely controlled fabrication allow these members to carry greater loads. Therefore, they are capable of spanning greater distances and supporting heavier live loads. Bridges using members of this type and material have been widely used in the United States since World War II.

Prestressed concrete is generally more economical than conventionally reinforced concrete because the prestressing force lowers the neutral axis, putting more of the concrete section into compression. Also, the prestress steel is very high strength, so fewer pounds of steel are needed (see Figure 3.1.9).

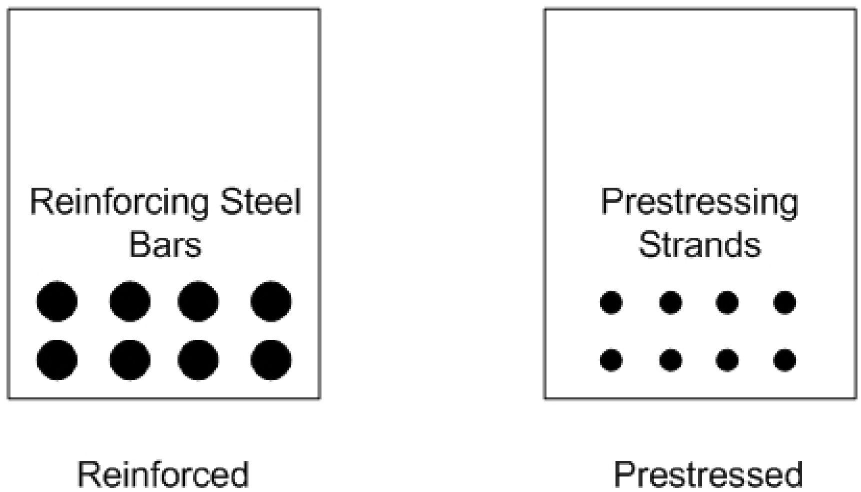


Figure 3.1.9 Non-prestressed Mild Steel Reinforced Concrete vs. Precast Prestressed Concrete

I-beams, distinguished by their "I" shape, function as superstructure members and support the deck. This type of beam can be used for spans as long as 150 feet.

Bulb-tee beams are distinguished by their "T" shapes, with a bulb-shaped section (similar to the bottom flange of an I-beam) at the bottom of the vertical leg of the tee. This type of beam can be used for spans as long as 200 feet.

Box beams, distinguished by a square or rectangular shape, usually have a beam depth greater than 17 inches. Box beams can be adjacent or spread, and they are typically used for short and medium span bridges. Adjacent box beams have practical span lengths that range 40 to 130 feet and spread box beams have practical span lengths that range up to 130 feet.

Box girders, distinguished by their trapezoidal or rectangular box shapes, function as both deck and superstructure. Box girders are used for long span or curved bridges and can be precast and erected in segments or cast in place. Spans lengths can range from 130 to 1000 feet.

Voided slabs, distinguished by their rectangular shape and their interior voids, are generally precast units supported by the substructure. The interior voids are used to reduce the dead load. Voided slabs can be used for spans up to 60 feet.

Axially-Loaded Compression Members

Concrete axially-loaded compression members are used in bridges in the form of:

- Columns
- Arches
- Piles

These members are conventionally reinforced to carry bending forces and to augment their compression load capacity.

Columns are straight members which can carry axial load, horizontal load, and bending and are used as substructure elements. Columns are commonly square, rectangular, or round.

An arch can be thought of as a curved column and is commonly used as a superstructure element. Concrete superstructure arches are generally square or rectangular in cross section.

Piles are slender columns that support the substructure footing or partially form the substructure. Piles may be partially above ground but are usually completely buried (see Figure 3.1.10). Concrete piles may be conventionally reinforced or prestressed.

Figure 3.1.10 Concrete Pile Bent

Iron Shapes

Iron was used predominately as a bridge material between 1850 and 1900. Stronger and more fire resistant than wood, iron was widely used to carry the expanding railroad system during this period.

There are two types of iron members: cast iron and wrought iron. Cast iron is formed by casting, whereas wrought iron is formed by forging or rolling the iron into the desired form.

Cast Iron

Historically, cast iron preceded wrought iron as a bridge material. The method of casting molten iron to form a desired shape was more direct than forging wrought iron.

Casting allowed iron to be formed into almost any shape. However, because of cast iron's brittleness and low tensile strength, bridge members of cast iron were best used to carry axial compression loads. Therefore, cast iron members were usually cylindrical or box-shaped to efficiently resist axial loads.

Wrought Iron

In the late 1800's, wrought iron virtually replaced the use of cast iron. The two primary reasons for this were that wrought iron was better suited to carry tensile loads and advances in rolling technology made wrought iron shapes easier to obtain and more economical to use. Advances in technology made it possible to form a variety of shapes by rolling, including:

- Rods and wire
- Bars
- Plates
- Angles
- Channels
- I-Beams

Steel Shapes

Steel bridge members began to be used in the United States in the late 1800’s and, by 1900, had virtually replaced iron as a bridge material. The replacement of iron by steel was the result of advances in steel making (see Figure 3.1.11). These advances yielded a steel material that surpassed iron in both strength and elasticity. Steel could carry heavier loads and better withstand the shock and vibration of ever-increasing live loads. Since the early 1900’s, the quality of steel has continued to improve. Stronger and more ductile A36, A572, A588, and, more recently, HPS steels have replaced early grades of steel, such as A7.

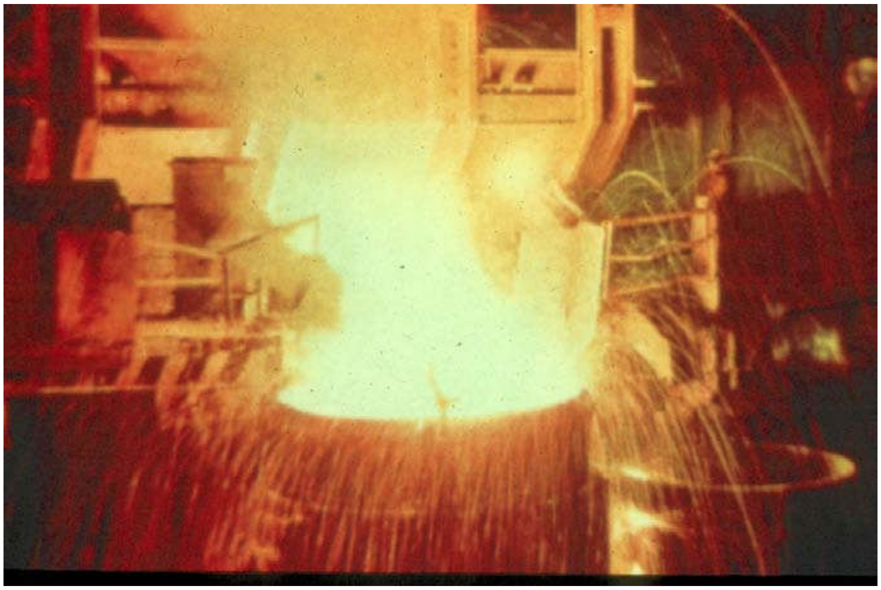


Figure 3.1.11 Steel Making Operation

Due to their strength, steel bridge members are used to carry axial forces as well as bending forces. Steel shapes are generally either rolled or built-up.

Rolled Shapes

Rolled steel shapes commonly used on bridges include (see Figure 3.1.12):

- Bars and plates
- Angles
- Channels
- S Beams (American standard "I" beams)
- W Beams (Wide flange "I" beams

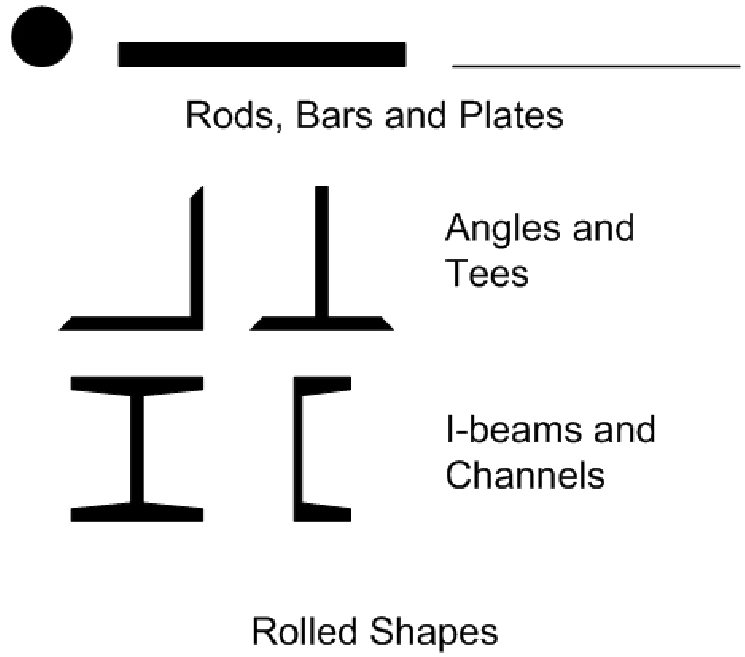


Figure 3.1.12 Common Rolled Steel Shapes

The standard weights and dimensions of these shapes can be found in the American Institute of Steel Construction (AISC) *Manual of Steel Construction*.

Bars and plates are flat pieces of steel. Bars are normally considered to be up to 8 inches in width. Common examples of bars include lacing bars on a truss and steel eyebars. Plates are designated as flat plates if they are over 8 inches in width. A common example of a plate is the gusset plate on a truss. Bars and plates are dimensioned as follows: width x thickness x length. Examples of bar and plate dimensions include:

- Lacing bar: 2" x 3/8" x 1'-3"
- Gusset plate: 21" x 1/2" x 4'-4”

Angles are “L”-shaped members, the sides of which are called “legs”. Each angle has two legs, and the width of the legs can either be equal or unequal. When dimensioning angles, the two leg widths are given first, followed by the thickness and the length. Examples of angle dimensions include:

- L 4" x 4" x ¼" x 3'-2"
- 2L’s 5" x 3" x 3/8" x 1'-1"

Angles range in size from 1"x1"x1/4" to 8"x8"x1-1/8". Angles range in weight from less than 1 pound per foot to almost 60 pounds per foot.

Angles, bars, and plates are commonly connected to form bracing members (see Figure 3.1.13).

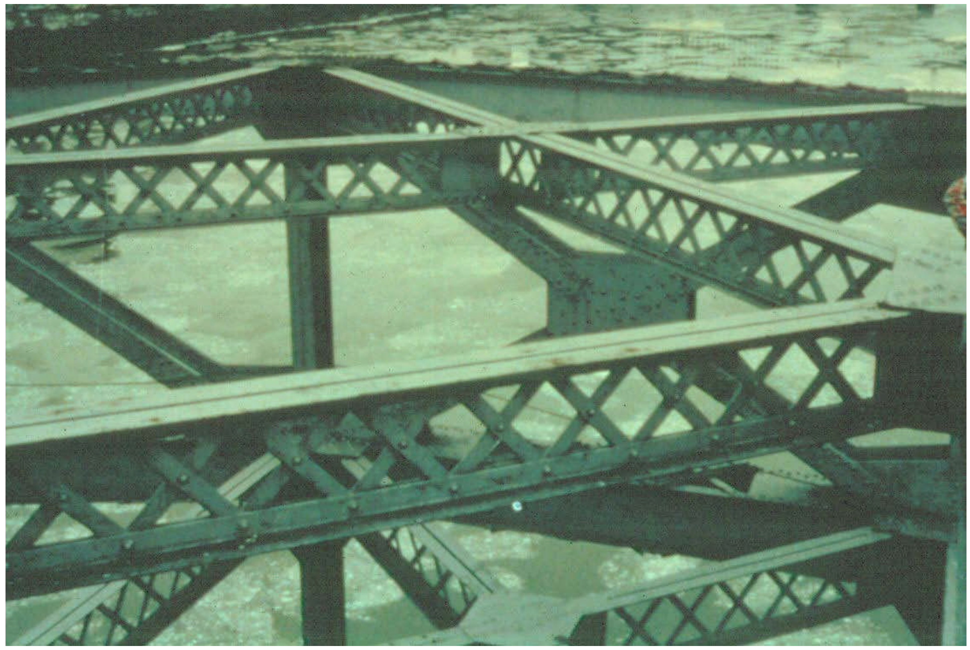


Figure 3.1.13 Bracing Members Made from Angles, Bars, and Plates

Channels are squared-off "C"-shaped members and are used as diaphragms, struts, or other bracing members. The top and bottom parts of a channel are called the flanges. Channels are dimensioned by the depth (the distance between outside edges of the flanges) in inches, the weight in pounds per foot, and the length in inches. Examples of channel dimensions include:

- C 9 x 15 x 9'-6"
- C 12 x 20.7 x 11'-2-1/2"

When measuring a channel, it is not possible for the inspector to know how much the channel section weighs. In order to identify a channel, measurements of the average thickness, flange width, the web depth, and the thickness are needed. From this information, the inspector can then determine the true channel designation through the use of reference books such as American Institute of Steel Construction (AISC) *Manual of Steel Construction*.

Standard channels range in depth from 3 inches to 15 inches, and weights range from less than 5 pounds per foot to 50 pounds per foot. Nonstandard sections (called miscellaneous channels or MC) are rolled to depths of up to 18 inches, weighing up to 60 pounds per foot.

Beams are “I”-shaped sections used as main load-carrying members. The load-carrying capacity generally increases as the member size increases. The early days of the iron and steel industry saw the various manufacturers rolling beams to their own standards. It was not until 1896 that beam weights and dimensions were standardized when the Association of American Steel Manufacturers adopted the American Standard beam. Because of this, I-beams are referred to by many designations, depending on their dimensions and the time period in which the particular shape was rolled. Today all I-beams are dimensioned according to their depth and weight per unit length.

Examples of beam dimensions include:

- S15x50 - an American Standard (hence the "S") beam with a depth of 15 inches and a weight of 50 pounds per foot
- W18x76 - a wide (W) flange beam with a depth of 18 inches and a weight of 76 pounds per foot

Some of the more common designations for rolled I-beams are:

- S = American Standard beam
- W = Wide flange beam
- WF = Wide flange beam
- CB = Carnegie beam
- M = Miscellaneous beam
- HP = H-pile

To identify an I-beam, measurements of the depth, the flange width and thickness, and the web thickness (if possible) are needed. With this information, the inspector can then determine the beam designation from reference books such as American Institute of Steel Construction (AISC) *Manual of Steel Construction*.

These beams normally range in depth from 3 to 36 inches and range in weight from 6 to over 300 pounds per foot. There are some steel mills that can roll beams up to 44 inches deep.

Built-up Shapes

Built-up shapes offer a great deal of flexibility in designing member shapes. As such, they allow the bridge engineer to customize the members for their particular need. Built-up shapes are fabricated by either riveting, bolting or welding techniques.

The practice of riveting steel shapes began in the 1800's and continued through the 1950's. Typical riveted shapes include truss members, girders and boxes.

Riveted girders are large I-beam members fabricated from plates and angles. These girders were used when the largest rolled beams were not large enough as required by design (see Figure 3.1.14).

Riveted boxes are large rectangular shapes fabricated from plates, angles, or channels. These boxes are used for cross-girders, truss chord members, and substructure members (see Figure 3.1.15).

As technology improved, riveting was replaced by high strength bolting and welding. Popular since the early 1960's, welded steel shapes include girders and boxes.

Welded girders are large I-beam members fabricated from plates. They are referred to as welded plate girders and have replaced the riveted girder (see Figure 3.1.16).

Welded boxes are large, rectangular-shaped members fabricated from plates. Welded boxes are commonly used for superstructure girders, truss members, and cross girders. Welded box shapes have replaced riveted box shapes (see Figure 3.1.17).

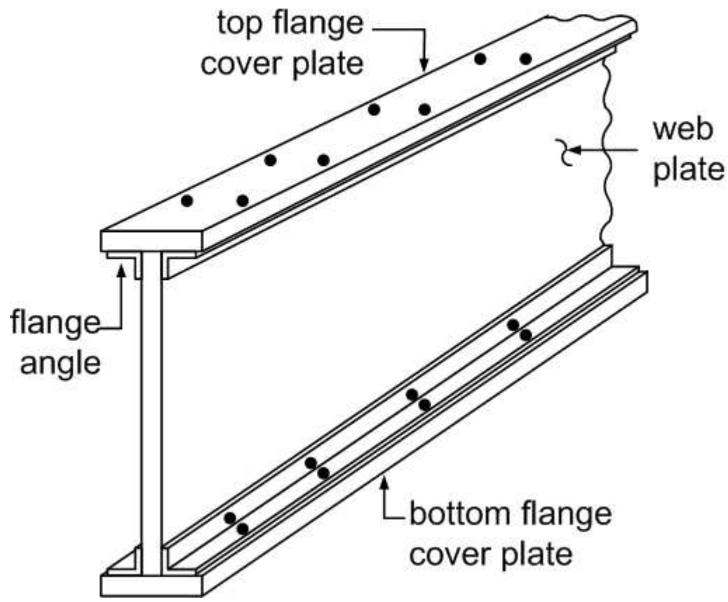


Figure 3.1.14 Riveted Plate Girder

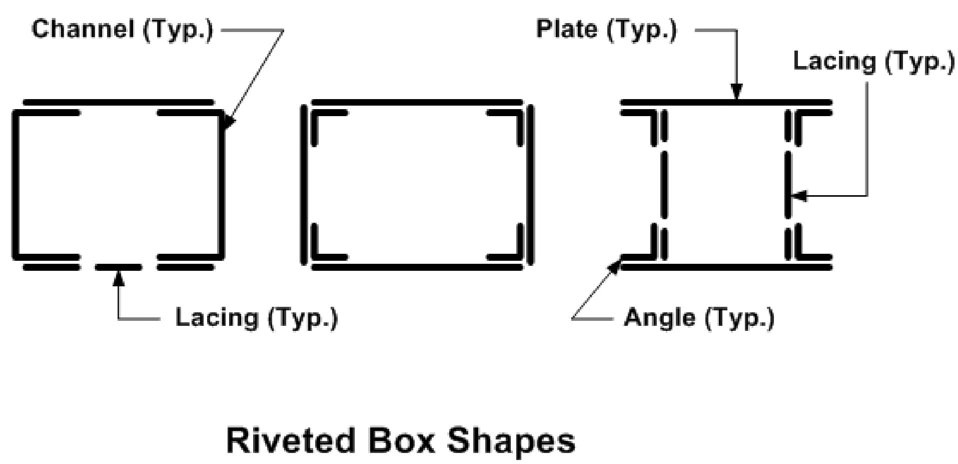


Figure 3.1.15 Riveted Box Shapes

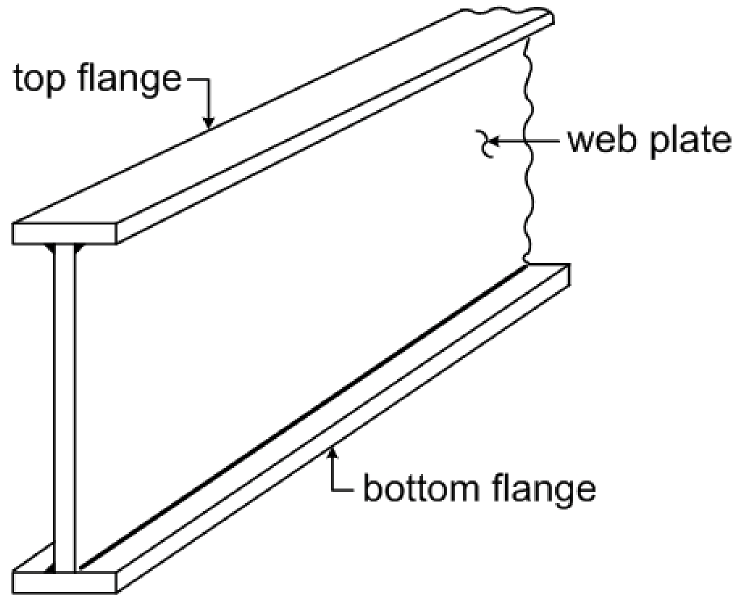


Figure 3.1.16 Welded I-Beam

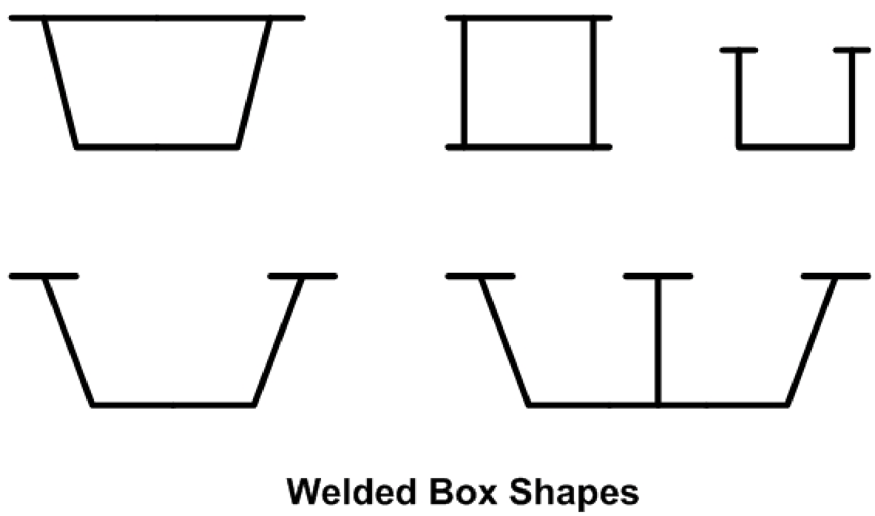


Figure 3.1.17 Welded Box Shapes

Cables

Steel cables (see Figure 3.1.18) are tension members and are used in suspension, tied-arch, and cable-stayed bridges. They are used as main cables and hangers of these bridge types (see Figure 3.1.19 and 3.1.20). Refer to Topic 16.1 for a more detailed description of cable-supported bridges.

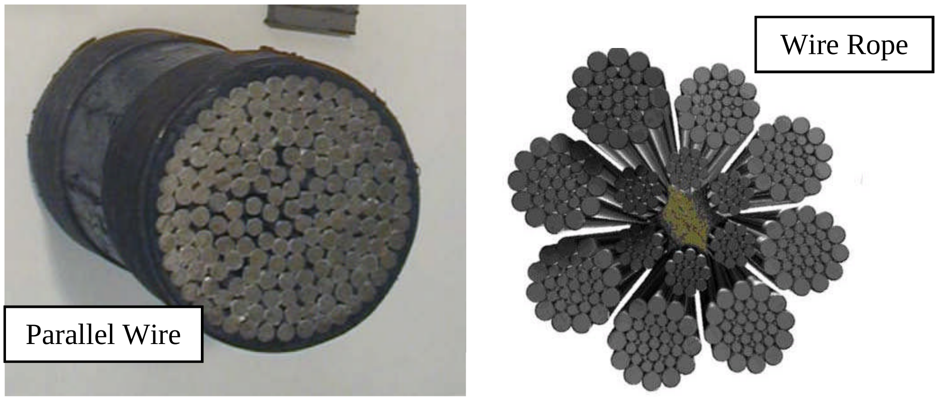


Figure 3.1.18 Cable Cross-Sections

Figure 3.1.19 Cable-Supported Bridge: Suspension Cables and Hangers

Figure 3.1.20 Cable-Supported Bridge: Cable Stayed

3.1.6 Connections

Rolled and built-up steel shapes are used to make stringers, floorbeams, girders, trusses, frames, arches and other bridge members. These members require structural joints, or connections, to transfer loads between members. There are several different types of bridge member connections:

- Pin connections
- Riveted connections
- Bolted connections
- Welded connections
- Pin and hanger assemblies
- Splice connections

Pin Connections

Pins are cylindrical bars produced by forging, casting, or cold-rolling. The pin sizes and configurations are as follows (see Figure 3.1.21):

- A small pin, 1-1/4 to 4 inches in diameter, is usually made with a cotter pin hole at one or both ends
- A medium pin, up to 10 inches in diameter, usually has threaded end projections for recessed retainer nuts
- A large pin, over 10 inches in diameter, is held in place by a recessed cap at each end and is secured by a bolt passing completely through the caps and pin

Pins are often surrounded by a protective sleeve, which may also act as a spacer to separate member elements. Pin connections are commonly used in eyebar trusses, hinged arches, pin and hanger assemblies, and bearing supports (see Figure 3.1.22).

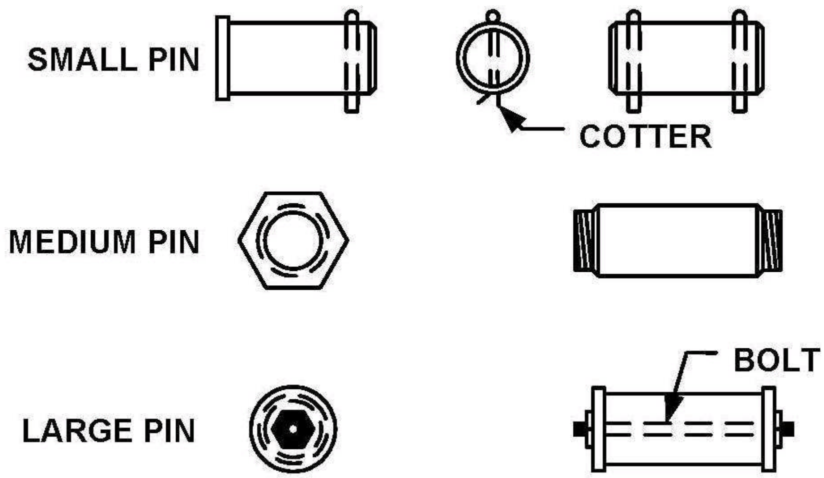


Figure 3.1.21 Sizes of Bridge Pins

Figure 3.1.22 Pin-Connected Eyebars

The major advantages of using pin connection details are the design simplicity and to facilitate rotation. The design simplicity afforded by pin connections reduces the amount and complexity of design calculations. By allowing for end rotation, pin connections reduce the level of stress in the member.

The major disadvantages of pin connection details are the result of vibration, pin wear, unequal eyebar tension, unseen corrosion, and poor inspectability. Vibrations increase with pin connections because they allow more movement than more rigid types of connections. As a result of increased vibration, moving parts are subject to wear.

Pin connections were commonly used in trusses, suspended girder spans and some bearings. These pin connections are susceptible to freezing due to corrosion. This results in changes in structural behavior and undesirable stresses when axially-loaded members must resist bending.

Some pins connect multiple eyebars. Since the eyebars may have different lengths, they may experience different levels of tension. In addition, because parts of the pin surface are hidden from view by the eyebars, links, or connected parts, an alternate method of completely inspecting the pin may be needed (e.g., ultrasonic testing or pin removal).

Riveted Connections

The rivet was the primary fastener used in the early days of iron and steel bridges. High strength bolts replaced rivets by the early 1960's.

The standard head is called a high-button or acorn-head rivet. Flat-head and countersunk-head rivets were also used in areas of limited clearance, such as a hanger connection (see Figure 3.1.23).

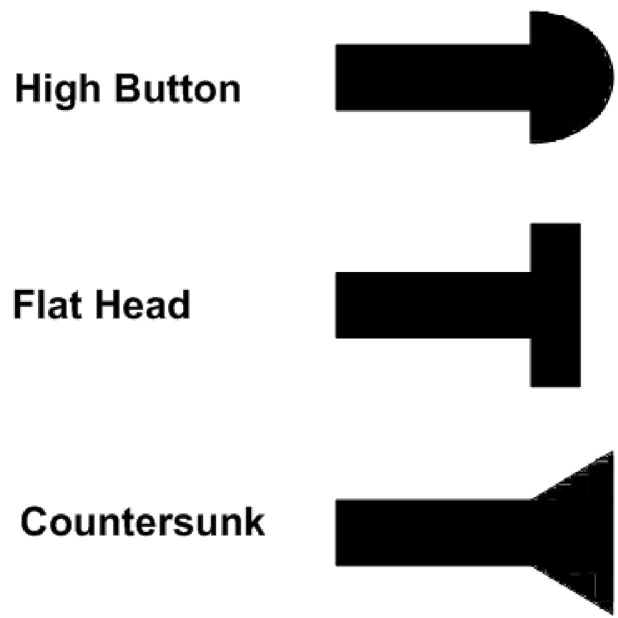


Figure 3.1.23 Types of Rivet Heads

There are two grades of rivets typically found on bridges:

- ASTM A502 Grade 1 (formerly ASTM A141) low carbon steel
- ASTM A502 Grade 2 (formerly ASTM A195) high strength steel

The rivet sizes most often used on bridges were 3/4, 7/8, or 1-inch shank diameters. Rivet holes were generally 1/16-inch larger than the rivet shank. While the hot rivet was being driven, the shank would increase slightly, filling the hole. As the rivet cooled, it would shrink in length, clamping together the connected elements.

When the inspector can feel vibration on one head of the rivet while hitting the other rivet head with a hammer, this generally indicates that the rivet is loose. This method may not work with sheared rivets clamped between several plates.

Bolted Connections

Research into the use of high strength bolts began in 1947. The first specifications for the use of such bolts were published in 1951. The economic and structural advantages of bolts over rivets led to their rapid use by bridge engineers. Bridges constructed in the late 1950's may have a combination of riveted (shop) and bolted (field) connections (see Figure 3.1.24).

Structural bolts consist of three basic material designations:

- ASTM A307 low carbon steel
- ASTM A325 (AASHTO M 164) high strength steel
- ASTM A490 (AASHTO M 253) high strength alloy steel

For further information on the bolts listed above or any other material properties visit the American Society for Testing and Materials International website at: www.astm.org .

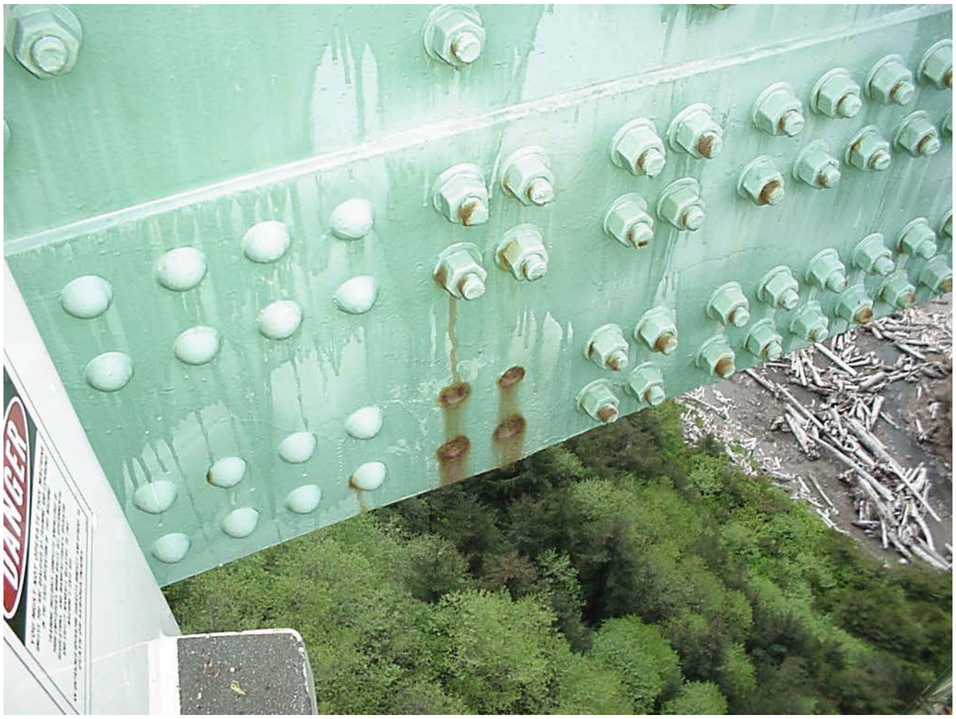


Figure 3.1.24 Shop Rivets and Field Bolts

The most commonly used bolts on bridges are 3/4, 7/8, and 1-inch in diameter. Larger bolts are often used to anchor the bearings. Bolt holes are typically 1/16-inch larger than the bolt. However, oversized and slotted holes are also permissible if properly detailed.

Tightening high strength bolts puts them in tension, which clamps the member elements together. Although proper installation of new high strength bolts can be verified the use of a torque wrench, this method does not have any merit when inspecting high strength bolts on in-service bridges. The torque is dependent on factors such as bolt diameter, bolt length, connection design (bearing or friction), use of washers, paint and coatings, parallelism of connected parts, dirt, and corrosion. Simple methods, such as visual observation, striking with a hammer and listening or feeling for loose bolts, are the most common methods used by inspectors when inspecting bolts.

Welded Connections

Pins, rivets, and bolts are examples of mechanical fasteners. A welded connection is not mechanical but rather is a rigid one-piece construction. A properly designed and executed welded joint, in which two pieces are fused together, is as strong as the joined materials.

Similar to mechanical fasteners, welds are used to make structural connections between members and also to connect elements of a built-up member. Welds have also been used in the fabrication and erection of bridges as a way to temporarily hold pieces together prior to field riveting, bolting, or welding. Small temporary erection welds, known as tack welds, can cause serious fatigue problems to certain bridge members (see Figure 3.1.25). Fatigue and fracture of steel bridge members are discussed in detail in Topic 6.4 (refer to 6.4.3 for factors affecting fatigue crack initiation). Welding is also used as a means of sealing joints and seams from moisture.

Figure 3.1.25 Close-up of Tack Weld on a Riveted Built-up Truss Member

The first specification for using welds on bridges appeared in 1936. Welding eventually replaced rivets for fabricating built-up members. Welded plate girders, hollow box-like truss members, and shear connectors for composite decks are just a few of the advances attributed to welding technology.

Welds need to be carefully inspected for cracks or signs of cracks (e.g., broken paint or rust stains) in both the welds and the adjoining base metal elements.

Pin and Hanger Assemblies

A pin and hanger assembly is a type of hinge consisting of two pins and two hangers. Pin and hanger assemblies are used in an articulated (continuous bridge with hinges) or a suspended span configuration. The location of the assembly varies depending on the type of bridge. In I-beam bridges, a hanger is located on either side of the webs (see Figure 3.1.26). In suspended span truss bridges, each assembly has a hanger which is similar in shape to the other connecting members (with the exception of the pinned ends). Pin and hangers were used to simply design before computer programs were developed to aid design of continuous bridges.

Figure 3.1.26 Pin and Hanger Assembly

Pin and hanger assemblies must be carefully inspected for signs of wear and corrosion. A potential problem can occur if corrosion of the pin and hanger causes the assembly to "freeze," inhibiting free rotation. This condition does not allow the pin to rotate and results in additional stresses in the pin and hanger and adjacent members. The failure of a pin and hanger assembly may cause a partial or complete failure of the bridge.

Splice Connections

A splice connection is the joining of two sections of the same member, either in the fabrication shop or in the field. This type of connection can be made using rivets, bolts, or welds. Bolted splices are common in multi-beam superstructures due to the limited allowable shipping lengths (see Figure 3.1.27). Shop welded flange splices are common in large welded plate girders and long truss members.

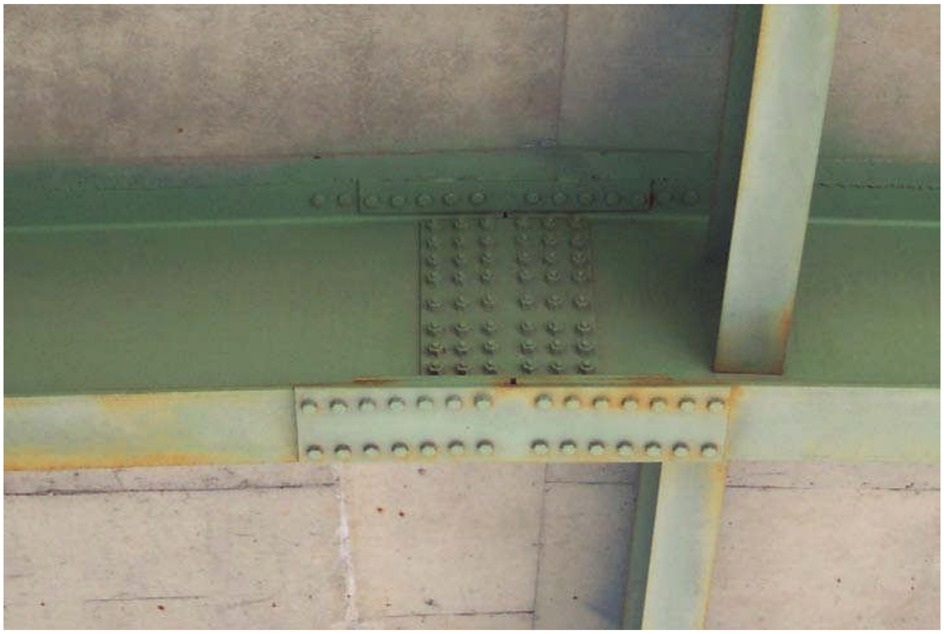


Figure 3.1.27 Bolted Field Splice

3.1.7 Decks

The deck is that component of a bridge to which the live load is directly applied. Refer to Chapter 7 for a detailed explanation on the inspection and evaluation of decks.

Deck Purpose

The purpose of the deck is to provide a smooth and safe riding surface for the traffic utilizing the bridge (see Figure 3.1.28).

Figure 3.1.28 Bridge Deck with a Smooth Riding Surface

The function of the deck is to transfer live loads and dead loads of and on the deck to other bridge components commonly referred to as the superstructure (see Figure 3.1.29). However, on some bridges (e.g., a concrete slab bridge), the deck and the superstructure are one unit which distributes the live load directly to the substructure.

Figure 3.1.29 Underside View of a Bridge Deck

Deck Types

Decks function in one of two ways:

- Composite decks - act together with their supporting members and increase superstructure capacity (see Figures 3.1.30 and 3.1.31)
- Non-composite decks - are not integral with their supporting members and do not contribute to structural capacity of the superstructure

An inspector reviews the plans to determine if the deck is composite with the superstructure.

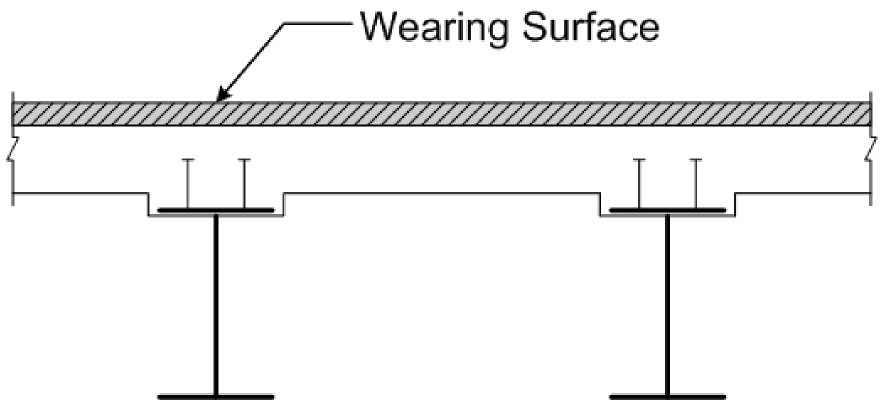


Figure 3.1.30 Composite Deck and Steel Superstructure

Figure 3.1.31 Shear Studs on Top Flange of Girder (before Concrete Deck is Placed)

Deck Materials

There are three common materials used in the construction of bridge decks:

- Timber
- Concrete
- Steel

Fiber Reinforced Polymer (FRP) has been used, but are not as common.

Timber Decks

Timber decks are often referred to as decking or timber flooring, and the term is limited to the roadway portion which receives vehicular loads. Refer to Topic 7.1 for a detailed explanation on the inspection and evaluation of timber decks.

Five basic types of timber decks are:

- Plank deck (see Figure 3.1.32)
- Nailed laminated deck
- Glued-laminated deck planks
- Stressed-laminated decks
- Structural composite lumber decks

Figure 3.1.32 Plank Deck

Concrete Decks

Concrete permits casting in various shapes and sizes and has provided the bridge designer and the bridge builder with a variety of construction methods. Because concrete is weak in tension, it is used together with reinforcement to resist tensile stresses (see Figure 3.1.33). Refer to Topic 7.2 for a detailed explanation on the inspection and evaluation of concrete decks.

There are several common types of concrete decks:

- Conventionally reinforced cast-in-place - removable or stay-in-place forms
- Precast conventionally reinforced
- Precast prestressed
- Precast prestressed deck panels with cast-in-place topping

Figure 3.1.33 Concrete Deck

Steel Decks

Steel decks are decks composed of either solid steel plate or steel grids (see Figure 3.1.34). Refer to Topic 7.4 for a detailed explanation on the inspection and evaluation of steel decks.

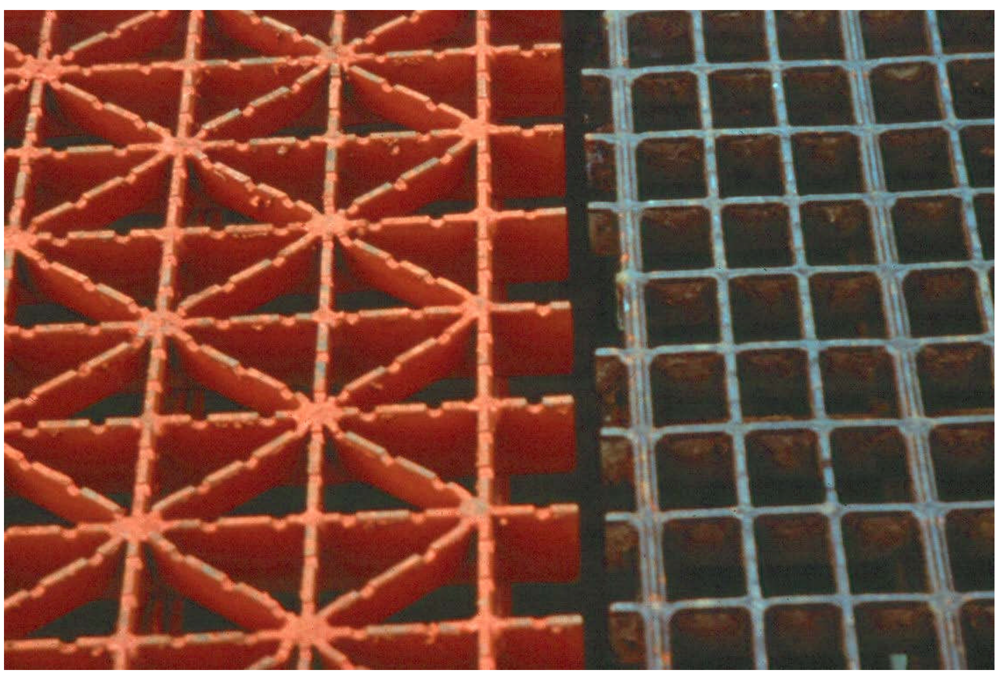


Figure 3.1.34 Steel Grid Deck

There are four common types of steel decks:

- Orthotropic deck
- Buckle plate deck (still exist on some older bridges but are no longer used)
- Corrugated steel flooring
- Grid Deck - open, filled, or partially filled

Fiber Reinforced Polymer (FRP) Decks

With the rise of technological development, innovative material such as fiber-reinforced polymer (FRP) bridge decking has begun replacing existing highway bridge decks. Though FRP material is more expensive than conventional bridge materials such as concrete, it has several advantages. These include lighter weight for efficient transport, better resistance to earthquakes, and easier installation. FRP bridge decking is also less affected by water and de-icing salts, which corrode steel and deteriorate concrete (see Figure 3.1.35). Refer to Topic 7.3 for a detailed explanation on the inspection and evaluation of FRP decks.

Figure 3.1.35 Fiber Reinforced Polymer (FRP) Deck

Wearing Surfaces

Constant exposure to the elements makes weathering a significant cause of deck deficiency. In addition, vehicular traffic produces damaging effects on the deck surface. For these reasons, a wearing surface is often applied to the surface of the deck. The wearing surface is the topmost layer of material applied to the deck to provide a smooth riding surface and to protect the deck from the effects of traffic and weathering.

A timber deck may have one of the following wearing surfaces:

- Timber planks – running boards
- Bituminous
- Concrete
- Gravel
- Polymers

Concrete decks may have wearing surfaces of:

- Concrete – latex modified concrete (LMC), low slump dense concrete (LSDC), lightweight concrete (LWC), fiber reinforced concrete (FRC), micro-silica modified concrete
- Bituminous (see Figure 3.1.36)
- Polymers - epoxy, polyester, methyl methacrylates

Figure 3.1.36 Asphalt Wearing Surface on a Concrete Deck

Steel decks may have wearing or riding surfaces of:

- Serrated steel
- Concrete
- Asphalt
- Polymers

Deck Appurtenances, Signing and Lighting

Deck Joints

The primary function of a deck joint is to accommodate the expansion, contraction, and rotation of the superstructure. The joint must also provide a smooth transition from an approach roadway to a bridge deck, or between adjoining segments of bridge deck. Refer to Topic 7.5 for detailed explanation on the inspection and evaluation of deck joints.

There are six categories of deck joints:

- Strip seal expansion joints (see Figure 3.1.37)
- Pourable joint seals
- Compression joint seals (see Figure 3.1.38)
- Assembly joints with seal (Modular)
- Open expansion joints
- Assembly joints without seals (finger plate and sliding plate joints) (see Figure 3.1.39)

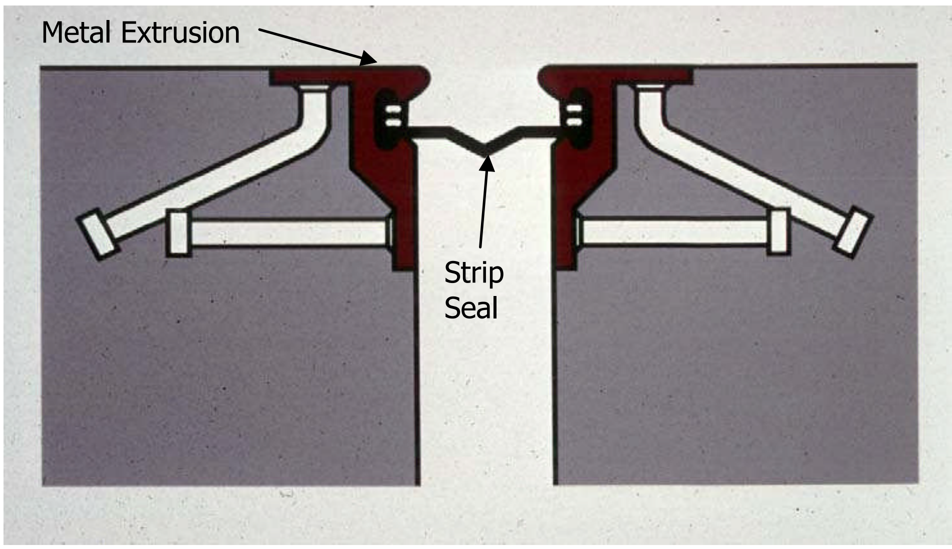


Figure 3.1.37 Strip Seal Expansion Joint

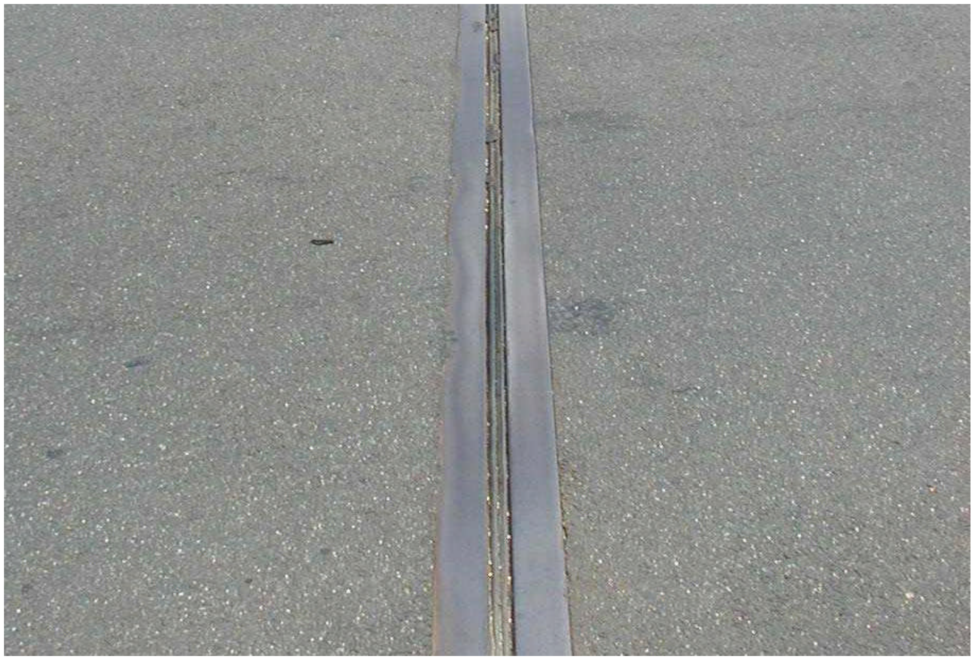


Figure 3.1.38 Top View of an Armored Compression Seal in Place

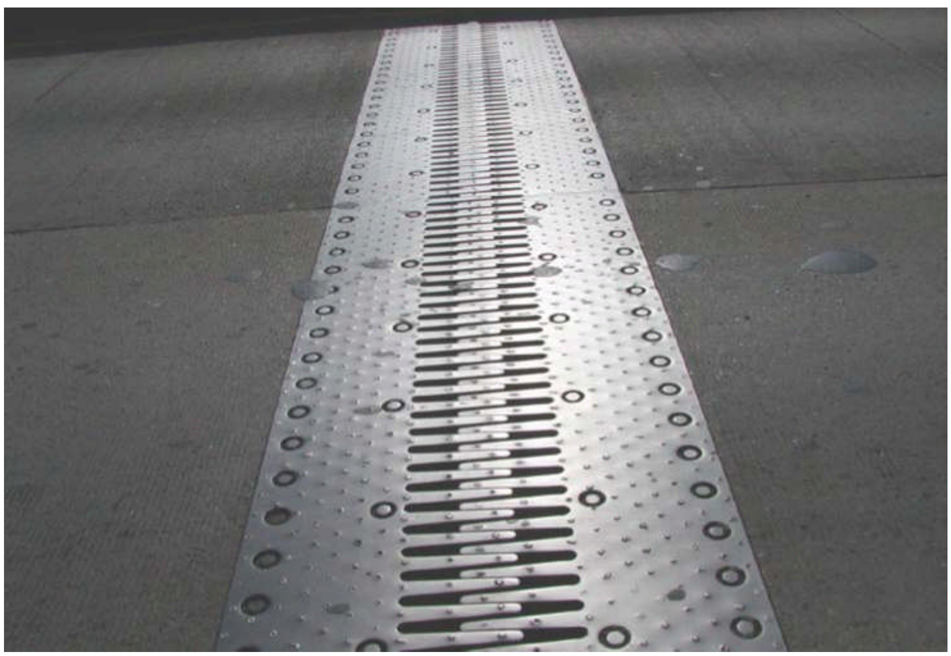


Figure 3.1.39 Top View of a Finger Plate Joint

Drainage Systems

The primary function of a drainage system is to remove water from the bridge deck, from under unsealed deck joints and from behind abutments and wingwalls. Refer to Topic 7.5 for detailed explanation on the inspection and evaluation of drainage systems.

A deck drainage system has the following components:

- Grade and cross slope
- Inlets
- Outlet pipes
- Downspout pipes - to transport runoff to storm sewers
- Cleanout plugs - for maintenance
- Drainage troughs
- Support brackets/hardware

A joint drainage system is typically a separate gutter or trough used to collect water passing through a finger plate or sliding plate joint.

Combining all these drainage components forms a complete deck drainage system.

Substructure drainage allows the fill material behind an abutment or wingwall to drain any accumulated water.

Substructure drainage is accomplished with weep holes or substructure drain pipes.

Traffic Safety Features

The proper and effective use of traffic barriers minimizes hazards for traffic on the bridge, on the highways, and waterways beneath the bridge.

Bridge barriers can be broken down into two categories:

- Bridge railing - to guide, contain, and redirect errant vehicles
- Pedestrian railing - to protect pedestrians

Examples of railing include:

- Timber plank rail
- Steel angles and bars
- Concrete pigeon hole parapet
- Combination bridge-pedestrian aluminum or steel railing
- New Jersey barrier - a very common concrete barrier (see Figure 3.1.40)

Refer to Topic 7.6 for detailed explanation on the inspection and evaluation of traffic safety features.

Figure 3.1.40 New Jersey Barrier

Sidewalks and Curbs

The function of sidewalks and curbs is to provide access to and maintain safety for pedestrians and to direct water to the drainage system. Curbs serve to lessen the chance of vehicles crossing onto the sidewalk and endangering pedestrians.

Signing

Signing serves to inform the motorist about bridge or roadway conditions that may be hazardous. Refer to Topic 7.5 for detailed explanation on the inspection and evaluation of signing.

Several signs likely to be encountered are:

- Weight limit and/or lane restrictions (see Figure 3.1.41)
- Speed traffic marker
- Vertical clearance
- Lateral clearance
- Narrow underpass
- Informational and directional
- Object markers

Figure 3.1.41 Weight Limit Sign and Object Marker Signs

Lighting

Types of lighting that may be encountered on a bridge include the following (see Figure 3.1.42):

- Highway lighting
- Traffic control lights
- Aerial obstruction lights
- Navigation lights
- Signing lights
- Illumination and drawbridge operation flashing lights

Refer to Topic 7.5 for detailed explanation on the inspection and evaluation of lighting systems.

Figure 3.1.42 Bridge Lighting

3.1.8
Superstructure

Superstructure Purpose

The basic purpose of the superstructure is to carry loads from the deck across the span and to the bridge supports commonly referred to as the substructure. The superstructure is that component of the bridge which supports the deck or riding surface of the bridge, as well as the loads applied to the deck.

The function of the superstructure is to span a feature and to transmit loads from the deck to the bridge supports commonly referred to as the substructure. Bridges are categorized by their superstructure type. Superstructures may be characterized with regard to their function (i.e., how they transmit loads to the substructure). Loads may be transmitted through tension, compression, bending, or a combination of these three.

Superstructure Types

There are many different superstructure types such as:

- Slabs
- Single web beams/girders
- Box beams/girders (multi-web)
- Trusses
- Arches
- Rigid frames
- Cable-supported bridges
- Movable bridges
- Floating bridges

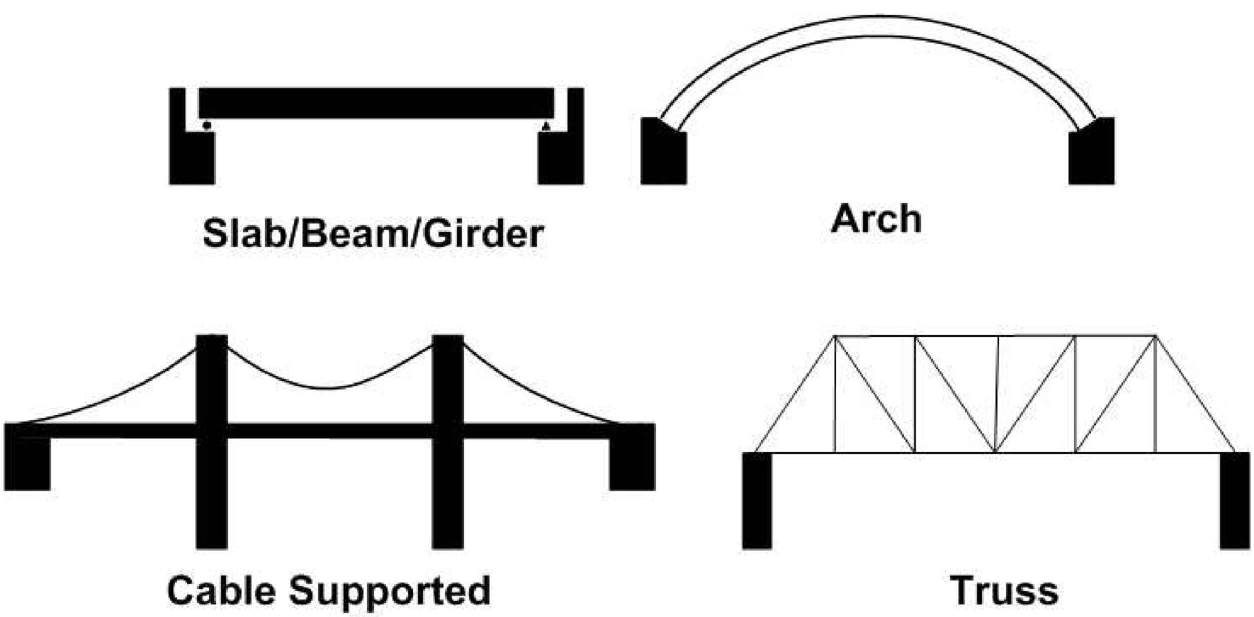


Figure 3.1.43 Four Basic Bridge Types

Slab Bridges

In slab bridges, loads from the slab are transmitted vertically to the substructure (see Figure 3.1.44).

Figure 3.1.44 Slab Bridge

Single Web Beam/Girder Bridges

In the case of beam and girder bridges, loads from the superstructure are transmitted vertically to the substructure. Examples of beam bridges include:

- Beams (timber, concrete, or steel) (see Figures 3.1.45, 3.1.49, 3.1.50)
- Girders (concrete or steel) (see Figures 3.1.46, 3.1.47, 3.1.48, 3.1.51)

Figure 3.1.45 Beam Bridge

Figure 3.1.46 Multi-Girder Bridge

Figure 3.1.47 Girder Floorbeam Stringer Bridge

Figure 3.1.48 Curved Girder Bridge

Figure 3.1.49 Tee Beam Bridge

Figure 3.1.50 Adjacent Box Beam Bridge

Figure 3.1.51 Box Girder Bridge

Trusses

Truss members including chords, verticals, and diagonals primarily carry axial tension and compression loads. Trusses can be constructed from timber or steel (see Figures 3.1.52 and 3.1.53).

Figure 3.1.52 Deck Truss Bridge

Figure 3.1.53 Through Truss Bridge

Arches

In the case of arch bridges, the loads from the superstructure are transmitted diagonally to the substructure. True arches are in pure compression. Arch bridges can be constructed from timber, concrete, or steel (see Figures 3.1.54 and 3.1.55).

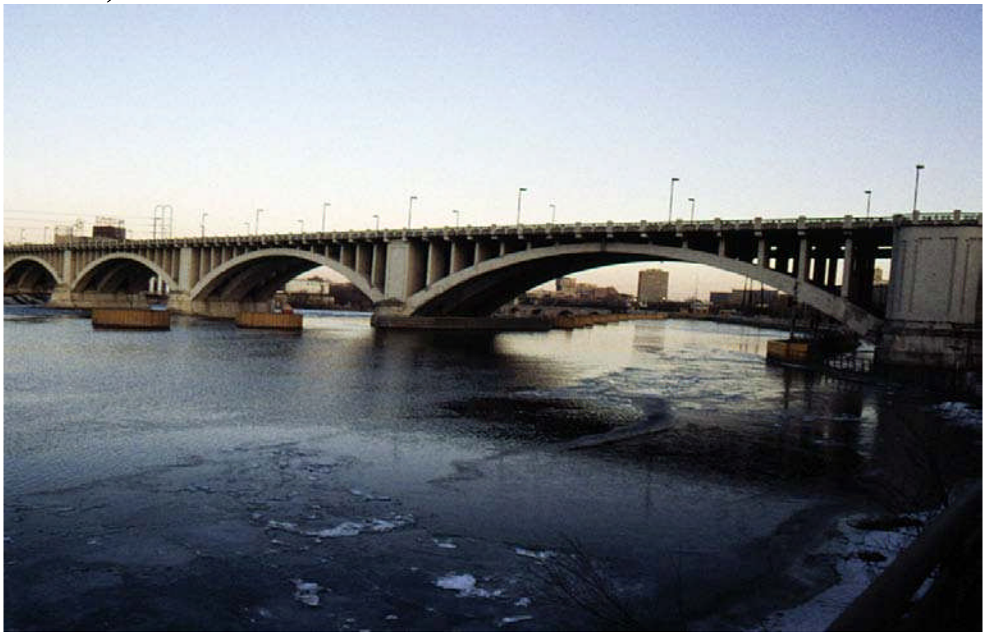


Figure 3.1.54 Deck Arch Bridge

Figure 3.1.55 Through Arch Bridge

Rigid Frames

Rigid frame superstructures are characterized by rigid (moment) connections between the horizontal girder and the legs. This connection allows the transfer of both axial forces and moments into vertical or sloping elements, which may be classified as superstructure or substructure elements depending on the exact configuration. Similar to beam/girder or slab configurations, rigid frame systems may be multiple parallel frames or may contain transverse floorbeams and longitudinal stringers to support the deck. (see Figure 3.1.56)

Figure 3.1.56 Rigid Frame

Cable-Supported Bridges

In the case of cable-supported bridges, the superstructure loads are resisted by cables which act in tension. The cable forces are then resisted by the substructure anchorages and towers. Cable-supported bridges can be either suspension or cable-stayed (see Figures 3.1.57 and 3.1.58). Refer to Topic 16.1 for a more detailed explanation on cable-supported bridges.

Figure 3.1.57 Suspension Bridge

Figure 3.1.58 Cable-stayed Bridge

Movable Bridges

Movable bridges are constructed across designated "Navigable Waters of the United States," in accordance with "Permit Drawings" approved by the U.S. Coast Guard or other agencies. The purpose of a movable bridge is to provide the appropriate channel width and underclearance for passing water vessels when fully opened. Refer to Topic 16.2 for a more detailed explanation on movable bridges.

Movable bridges can be classified into three general groups:

- Bascule (see Figure 3.1.59)
- Swing (see Figure 3.1.60)
- Lift (see Figure 3.1.61)

Figure 3.1.59 Bascule Bridge

Figure 3.1.60 Swing Bridge

Figure 3.1.61 Lift Bridge

Floating Bridges

Although uncommon, some states have bridges that are not supported by a substructure (see Figure 3.1.62). Instead, they are supported by water. The elevation of the bridge will change as the water level fluctuates.

Figure 3.1.62 Floating Bridge

Superstructure Materials

There are three common materials used in the construction of bridge superstructures:

- Timber
- Concrete
- Steel

Primary Members

Typical primary members carry primary live load from trucks and typically consist of the following:

- Girders (see Figure 3.1.63)
- Floorbeams (see Figure 3.1.63)
- Stringers (see Figure 3.1.63)
- Trusses
- Spandrel girders (see Figure (3.1.64)
- Spandrel columns (see Figure (3.1.64) or bents
- Arch ribs
- Rib chord bracing
- Hangers
- Frame girder
- Frame leg
- Frame knee
- Pin and hanger links

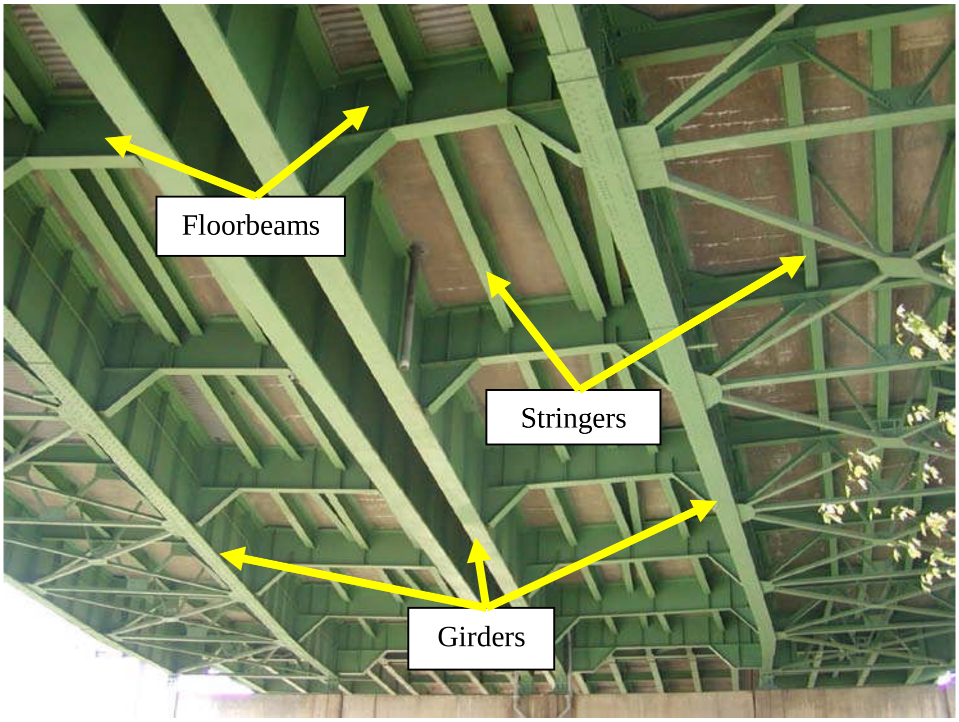


Figure 3.1.63 Floor System and Main Supporting Members

Additionally, diaphragms for curved girders may also be considered primary members. Vehicular live load is transmitted between the mains supporting members through the diaphragms in a curved multi-girder arrangement.

Figure 3.1.64 Main Supporting Members of Deck Arch

Secondary Members

Secondary members do not normally carry traffic loads directly. Typical secondary elements are:

- Diaphragms (see Figure 3.1.65)
- Cross or X-bracing (see Figure 3.1.66)
- Lateral bracing (see Figure 3.1.67)
- Sway-portal bracing (see Figure 3.1.67)
- Pin and hanger assemblies - Through bolts**,** pin caps, nuts, cotter pins on small assemblies, spacer washers, doubler plates

Figure 3.1.65 Diaphragms

Figure 3.1.66 Cross or X-Bracing

Figure 3.1.67 Top Lateral Bracing and Sway Bracing

3.1.9

Bearings

Bearing Purpose

A bridge bearing is an element which provides an interface between the superstructure and the bridge supports referred to as the substructure.

There are three primary functions of a bridge bearing:

- Transmit all loads from the superstructure to the substructure
- Permit longitudinal movement of the superstructure due to thermal expansion and contraction
- Allow rotation caused by dead and live load deflection

Bearings that do not allow for horizontal movement of the superstructure are referred to as fixed bearings. Bearings that allow for horizontal movement of the superstructure are known as expansion bearings. Both fixed and expansion bearings permit rotation. Refer to Topic 11.1 for more detailed explanation on expansion/fixed bearings.

Bearing Types

There are six bearing types that are utilized to accommodate superstructure movement and rotation:

- Elastomeric bearings
- Moveable bearings (roller, sliding, etc.)
- Enclosed/concealed bearings
- Fixed bearings
- Pot bearings
- Disk bearing

Refer to Topic 11.1 for detailed explanations on bridge bearing types.

Bearing Materials

There are two common materials used in the construction of bridge bearings:

- Steel
- Neoprene

Bearing Elements

A bridge bearing can be normally categorized into four basic elements (see Figure 3.1.68):

- Sole plate
- Bearing device
- Masonry plate
- Anchor bolts

Refer to Topic 11.1 for detailed explanations of these four bearing elements.

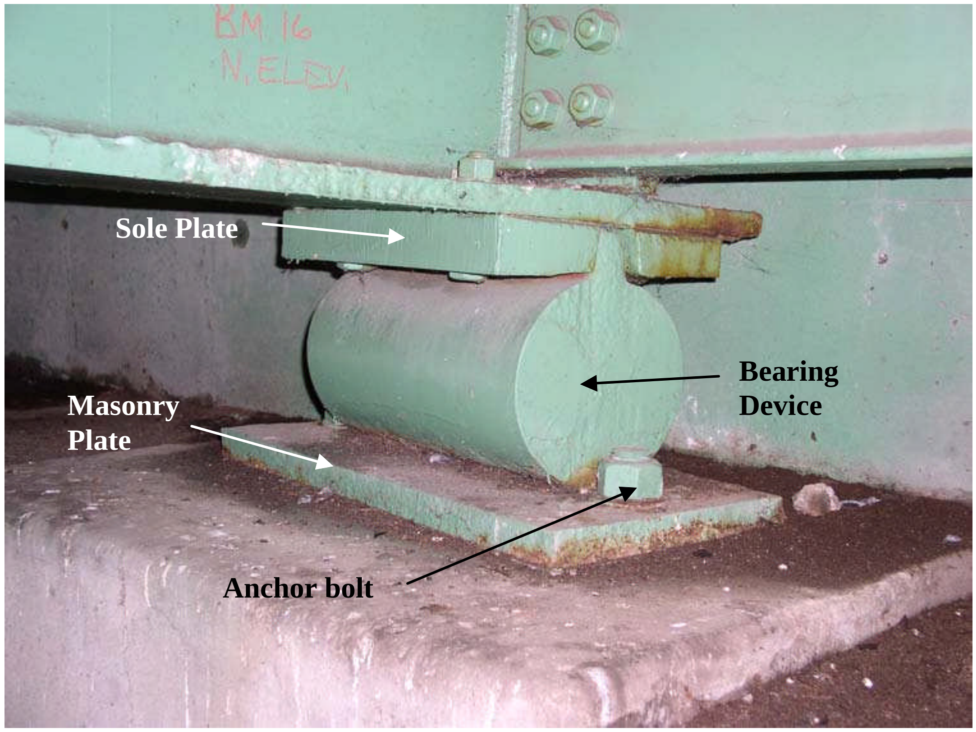


Figure 3.1.68 Steel Roller Bearing Showing Four Basic Elements

3.1.10 Substructure

The substructure is the component of a bridge which includes all the elements which support the superstructure.

Substructure Purposes

The purpose of the substructure is to transfer the loads from the superstructure to the foundation soil or rock. Typically the substructure includes all elements below the bearings. The loads are then distributed to the earth.

Substructure units function as both axially-loaded and bending members. These units resist both vertical and horizontal loads applied from the superstructure and roadway embankment. Substructures are divided into two basic categories:

- Abutments
- Piers and bents

Abutments provide support for the ends of the superstructure and retain the roadway approach embankment (see Figure 3.1.69). Piers and bents provide support for the superstructure at intermediate points along the bridge spans (see Figure 3.1.70).

Figure 3.1.69 Abutment

Figure 3.1.70 Pier

Substructure Types

Abutments

Basic types of abutments include:

- Cantilever or full height abutment - extends from the grade line of the roadway or waterway below, to that of the road overhead (see Figure 3.1.71).
- Stub, semi-stub, or shelf abutment - located within the topmost portion of the end of an embankment or slope. In the case of a stub, less of the

abutment stem is visible than in the case of the full height abutment. Most new construction uses this type of abutment. These abutments may be supported on deep foundations (see Figure 3.1.72).

- Spill-through or open abutment - consists of columns and has no solid wall, but rather is open to the embankment material. The approach embankment material is usually rock (see Figure 3.1.73).
- Integral abutment – superstructure and substructure are integral and act as one unit without an expansion joint or bearings. Relative movement of the abutment with respect to the backfill allows the structure to adjust to thermal expansions and contractions. Pavement relief joints at the ends of approach slabs are provided to accommodate the thermal movement between bridge deck and the approach roadway pavement (see Figure 3.1.74)

Figure 3.1.71 Cantilever Abutment (or Full Height Abutment)

Figure 3.1.72 Stub Abutment

Figure 3.1.73 Spill-Through or Open Abutment

Figure 3.1.74 Integral Abutment

Refer to Topic 12.1 for a more detailed explanation on bridge abutments.

Piers and Bents

A pier has only one footing at each substructure unit (the footing may serve as a pile cap). A bent has several footings or no footing, as is the case with a pile bent. Refer to Topic 12.2 for a more detailed explanation on bridge piers and bents.

There are four basic types of piers:

- Solid shaft pier (see Figures 3.1.75 and 3.1.76)
- Column pier (see Figure 3.1.77)
- Column pier with web wall (see Figure 3.1.78)
- Cantilever or hammerhead pier (see Figure 3.1.79)

Figure 3.1.75 Solid Shaft Pier

Figure 3.1.76 Solid Shaft Pier

Figure 3.1.77 Column Pier

Figure 3.1.78 Column Pier with Web Wall and Cantilevered Pier Caps

Figure 3.1.79 Cantilever or Hammerhead Pier

There are two basic types of bents:

- Column bent (see Figure 3.1.80)
- Pile bent (see Figure 3.1.81)

Figure 3.1.80 Column Bent

Figure 3.1.81 Pile Bent

Substructure Materials

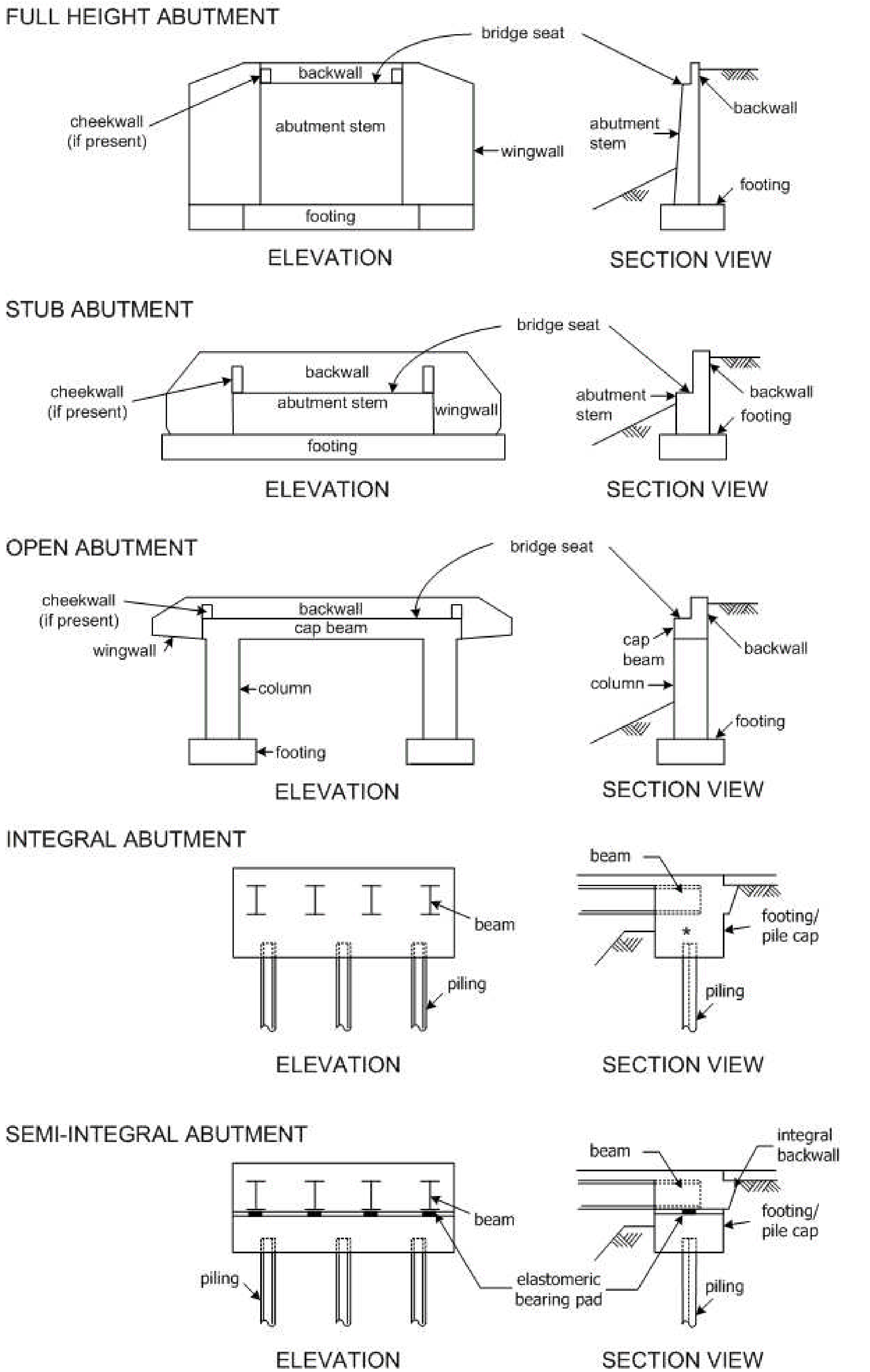
There are four common materials used in the construction of bridge substructures:

- Timber
- Concrete
- Steel
- Masonry

Substructure Elements

A bridge substructure can consist of several different elements (see Figure 3.1.82). Typical elements can include:

- Abutments
  - Backwall
  - Stem/bridge seat
  - Footing
  - Integral backwall



* Some states weld beam and piles prior to concrete placement

Figure 3.1.82 Schematic of Common Abutment Types

- Pier/Bents
    - Pier caps
    - Columns/Piles
    - Walls
    - Footing

Refer to Topics 12.1 and 12.2 for a detailed explanation of abutment, pier and bent elements.

3.1.11 Culverts

Culverts are often viewed as small bridges, being constructed entirely below and independent of the roadway surface. However, culverts do not have a deck, superstructure, or substructure. Culverts that are 20 feet or greater are defined as a bridge, according the NBIS definition for bridge length (see Topic 3.1.3).

Culvert Purpose

A culvert is primarily a hydraulic structure, and its main purpose is to transport water flow efficiently.

Culvert Materials

There are several common materials used in the construction of culverts:

- Concrete
- Masonry
- Steel
- Aluminum
- Timber
- Plastic

Refer to Topic 14.1 for a detailed explanation about culvert characteristics.

Culvert Types

Rigid Culverts

Rigid culverts can carry the load the same way a frame or an arch does by resisting the loads in bending and shear or frame an arch action (see Figure 3.1.83). Refer to Topic 14.2 for a detailed explanation of rigid culverts.

Figure 3.1.83 Rigid Culvert

Flexible Culverts

Flexible culverts will require lateral earth pressure to help maintain their shape. The loads are distributed through the flexible culvert and backfill. The backfill is critical to a flexible culverts performance (see Figure 3.1.84). Refer to Topic 14.3 for a detailed explanation of flexible culverts.

Figure 3.1.84 Flexible Culvert