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AIR FORCE AFJPAM 32-1088

BRIDGE INSPECTION, MAINTENANCE, AND REPAIR

DEPARTMENTS OF THE ARMY AND THE AIR FORCE
DECEMBER 1994

CHAPTER 1

INTRODUCTION

Section I. GENERAL INFORMATION

1-1. Purpose

This manual is a guide for the inspection, maintenance, and repair of bridges for military installations. It is a source of reference for planning, estimating, and technical accomplishment of maintenance and repair work and may serve as a training manual for facilities maintenance personnel in the Army and Air Force engaged in maintenance inspection and repair of bridges.

1-2. Scope

It provides guidance for typical maintenance and repair of bridges to retain them in continuous readiness for support of military operations. It also describes the methods used in accomplishing this maintenance and repair work. The text includes general principles of maintenance and repair for use by all activities designated to maintain bridges at Army and Air Force installations in a condition suitable for their intended use.

1-3. References

Appendix A contains a list of references used in this manual.

Section II. MAINTENANCE PLANNING

1-4. Programming and economic considerations

In maintenance planning and execution, full consideration must be given to future expected use of each bridge, the life expectancy of the bridge, and the life-cycle cost of periodic repairs versus replacement of a bridge or its major components. The level of maintenance and programming of major repairs should be planned in consonance with future requirement for the bridge and/or planned replacement. The maintenance program should be designed to include prevention of deterioration and damage, prompt detection of deficiencies, and early accomplishment of maintenance and repairs to prevent interruptions of operations or limitation/restriction of bridge use.

1-5. Elements of the maintenance program

a. Inspection. Continuous, rigorous inspections are necessary for an effective maintenance program. It is recommended that inspections be made annually of all basic structures and more frequently for fenders and utilities. Additional inspections may be necessary under certain circumstances, such as a tsunami, high tides, earthquakes, accidents, typhoons, and heavy freezes. Inspections may be made from the structures, from a boat or float, or below the waterline by divers. Underwater television is often employed in visual inspections. Types of inspections typical to bridges are:

(1) Operator inspection consists of examination, lubrication, and minor adjustment performed by operators on a continuous basis.

(2) Preventative maintenance inspection is the scheduled examination and minor repair of facilities and systems that would otherwise not be subject to inspection. Pier fender systems, fire protection systems, and under pier utilities are examples.

(3) Control inspection is the major scheduled examination of all components and systems on a periodic basis to determine and document the condition of the bridge and to generate major work required.

b. Maintenance. Maintenance is the recurrent day-to-day, periodic, or scheduled work that is required to preserve or restore a bridge to such a condition that it can be effectively utilized for its designed purpose. It includes work undertaken to prevent damage to or deterioration of a bridge that otherwise would be costly to restore. Several levels of bridge maintenance are practiced, depending on the complexity and frequency of the tasks involved. These tasks range from the clearing of drainpipes to the replacement of bearings. Minor maintenance consists of cleaning the drainage system, patch painting, removing debris, tightening loose bolts, and cleaning the joints.

(1) Routine maintenance includes adjusting bearings, complete repainting, repairing potholes, filling cracks, and sealing concrete.

(2) Major maintenance approaches rehabilitation in that it might include the replacement of bearings; readjustment of forces, such as in cables; replacement of joints; fatigue crack repair; waterway adjustment; and other specialized activities not performed very often.

Section III. FREQUENCY OF INSPECTION

1-6. Military requirements

a. Army. AR 420-72 requires that all bridges on all Army installations be thoroughly inspected every year and an analysis of load trying capacities be made every 3 years.

b. Air Force. Bridges on Air Force bases should be inspected at regular intervals not to exceed 2 years. Additionally, bridges should be inspected as soon as possible after severe storms (i.e., floods, hurricanes, etc.) to evaluate possible damage and reduced load-capacity of the structure. A structural analysis of its load-carrying capacity should be performed on at least every third inspection conducted.

1-7. Factors of frequency

a. The depth and frequency to which bridges are inspected will depend on the following factors: age, traffic characteristics, state of maintenance, known deficiencies, and climate conditions.

b. More frequent inspections shall be made if significant change has occurred as a result of floods, excessive loadings, earthquake, or accumulated deterioration. Where changes from those conditions existing in the original analysis and inspection or revalidation are apparent, a reanalysis of the load-carrying capacity shall be made.

Section IV. QUALIFICATIONS OF INSPECTION PERSONNEL

1-8. Army

a. Annual bridge inspection. Installation maintenance personnel should have a knowledge of bridge structure inspection and construction and be able to identify the regular maintenance requirement and structural deficiency.

b. Triennial bridge inspection. Bridge inspector should have the following minimum qualifications:

(1) Inspector should be a registered professional engineer (or under the direct supervision of a registered professional engineer).

(2) Inspector should have a minimum of 2 years experience in bridge inspection assignment in a responsible capacity.

(3) Inspector should be thoroughly familiar with design and construction features of the bridge to properly interpret what is observed and reported.

(4) Inspector should be capable of determining the safe load carrying capacity of the structure.

(5) Inspector should be able to recognize any structural deficiency, assess its seriousness, and take appropriate action necessary to keep the bridge in a safe condition.

(6) Inspector should also recognize areas of the bridge where a problem is incipient so that preventative maintenance can be properly programmed.

(7) The qualifications of each person directly or indirectly involved with the inspection should be submitted with bid documents.

1-9. Air Force

The Air Force inspector should be a trained bridge inspector from Maintenance Engineering. The main responsibilities are to perform the required inspections, document conditions of the structure, and initiate maintenance actions. If the inspection reveals a situation that requires a greater in-depth evaluation, the inspector (through the division chief) should request a design engineer to evaluate the bridge condition and determine corrective maintenance/repair actions.

CHAPTER 2

BRIDGE STRUCTURES

2-1. Definition

For the purpose of this manual, a bridge is defined as a structure, including supports, erected over a depression or an obstruction, such as water, highway, or railway, 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 or arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between opening is less than one-half of the smaller contiguous opening.

2-2. Classification

The inspector must be aware of bridge types to properly describe a bridge for the inspection report. The main emphasis of the description should be on the main span. Bridges are classified according to their function, structural type, and structural material:

a. Function. The "function" of a bridge refers to the currently approved classification of the roadway. Some typical roadway classifications are: interstate, freeway, principal arterial, minor arterial, collector, major, minor, military, etc.

b. Structural type. The "type" of bridge defines both the structural framing system and the type of superstructure:

(1) *Structural framing system.* There are basically four types of structural framing systems: simple spans, continuous spans, cantilever and suspended spans, and rigid frames. They are described as follows:

(a) Simple span. These spans consist of a superstructure span having a single unrestrained bearing at each end. The supports must be such that they allow rotation as the span flexes under load. Ordinarily, at least one support is attached in a way that keeps the span from moving longitudinally. Figure 2-1 (part a) demonstrates a simple span.

(b) Continuous span. Spans are considered continuous when one continuous piece crosses three or more supports. Figure 2-1 (part b) shows a two-span continuous structure. Note that the supports at the ends of the continuous units are similar to those at the ends of a simple span. However, because the member is continuous over the center support, the magnitude of the member rotation is restricted in the area adjacent to the pier. A bridge may be continuous over many supports with similar rotational characteristics over each interior support.

(c) Cantilever and suspended spans. Sometimes it is advantageous from a structural standpoint to continue a span over the pier and terminate it near the pier with a short cantilever. This cantilever is ordinarily used to support or "suspend" the end of an adjacent span. This arrangement is shown in figure 2-1 (part c). The other end of the suspended span may in some cases be supported by another cantilever or it may rest on an ordinary simple support.

(d) Rigid frames. These are frequently used as transverse supports in steel construction and occasionally used as longitudinal spans. The term "rigid" is derived from the manner of construction or fabrication which does not allow relative rotation between the members at a joint. A rigid frame may be rigidly attached at the base (fixed), or it may be simply supported.

(2) *Superstructure type.* The various types of superstructures are: slab, truss, girder, arch, suspension (not covered in this manual), beam-girder, stringer, and composite.

c. Structural material. The basic types of structural materials are steel, concrete, timber, stone, masonry, wrought iron, cast iron, and aluminum.

2-3. Typical bridges

Based upon the above classification criteria, many typical bridges can be defined and are summarized in figures 2-2 through 2-5.

2-4. Box culverts

Box culverts range in size from small, single-cell units to multicell units as large as 20 by 20 feet. While natural rock, when present, may be used as a floor, the box culvert is usually a closed, rectangular frame. Usually, transverse joints are provided every 20 to 30 feet. Occasionally, old culverts consist of simply a slab on a wall. These are not true box culverts. Some of these slabs are made of stone, while some walls are made of rubber masonry, rather than concrete.

2-5. Military bridges

A large variety of special-purpose military bridges exist. These bridges, for the most part, are designed for expedient deployment under combat situations. They are not intended for continued day-to-day usage under civilian and military traffic. However, due to economic constraints, some of these bridges are serving as "permanent" structures on some military installations. Therefore, the inspection, maintenance, and repair of these bridges must also be addressed. Several types of military bridges are shown in figures 2-6 through 2-10.

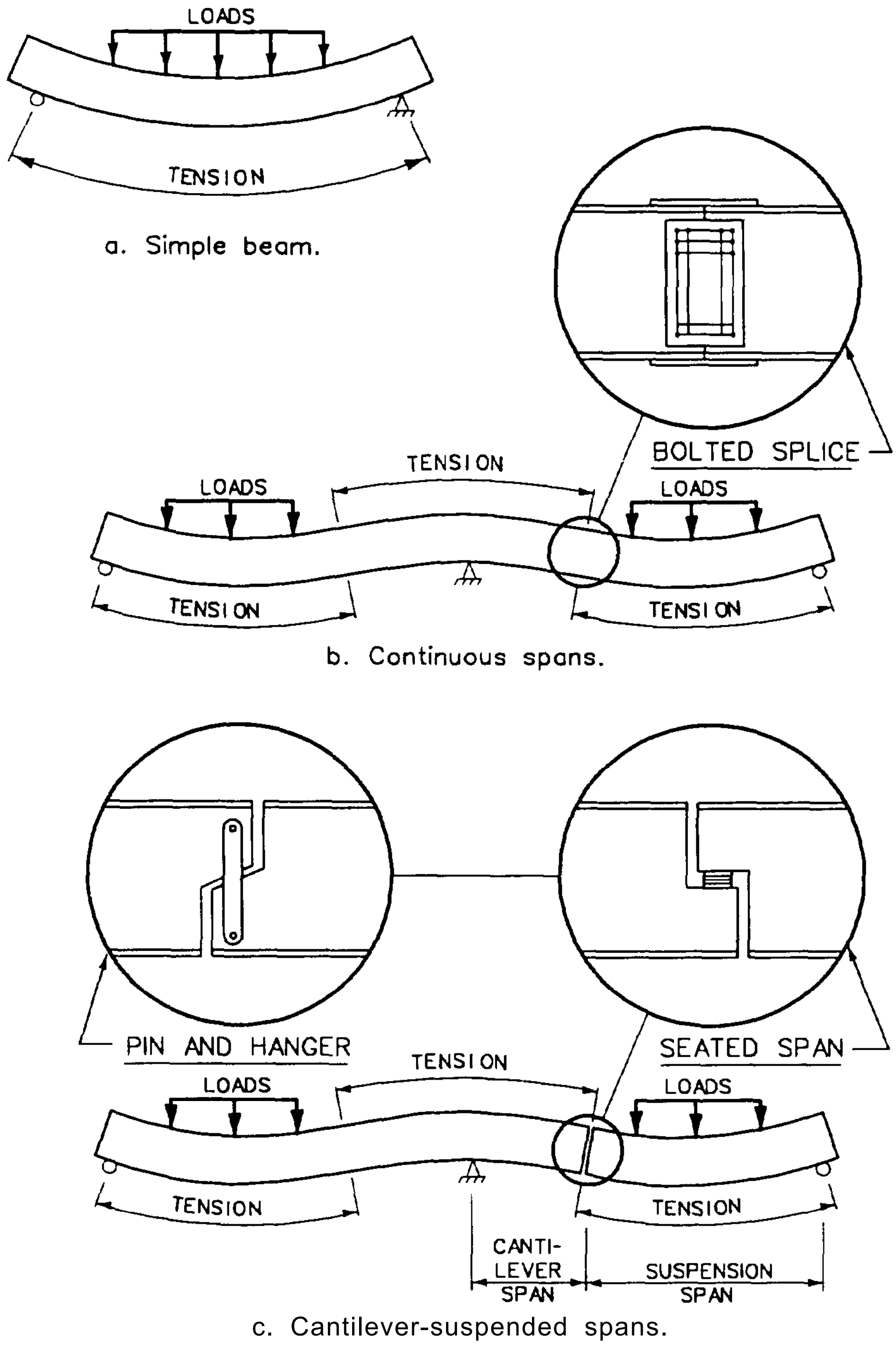


Figure 2-1. Structural framing system.

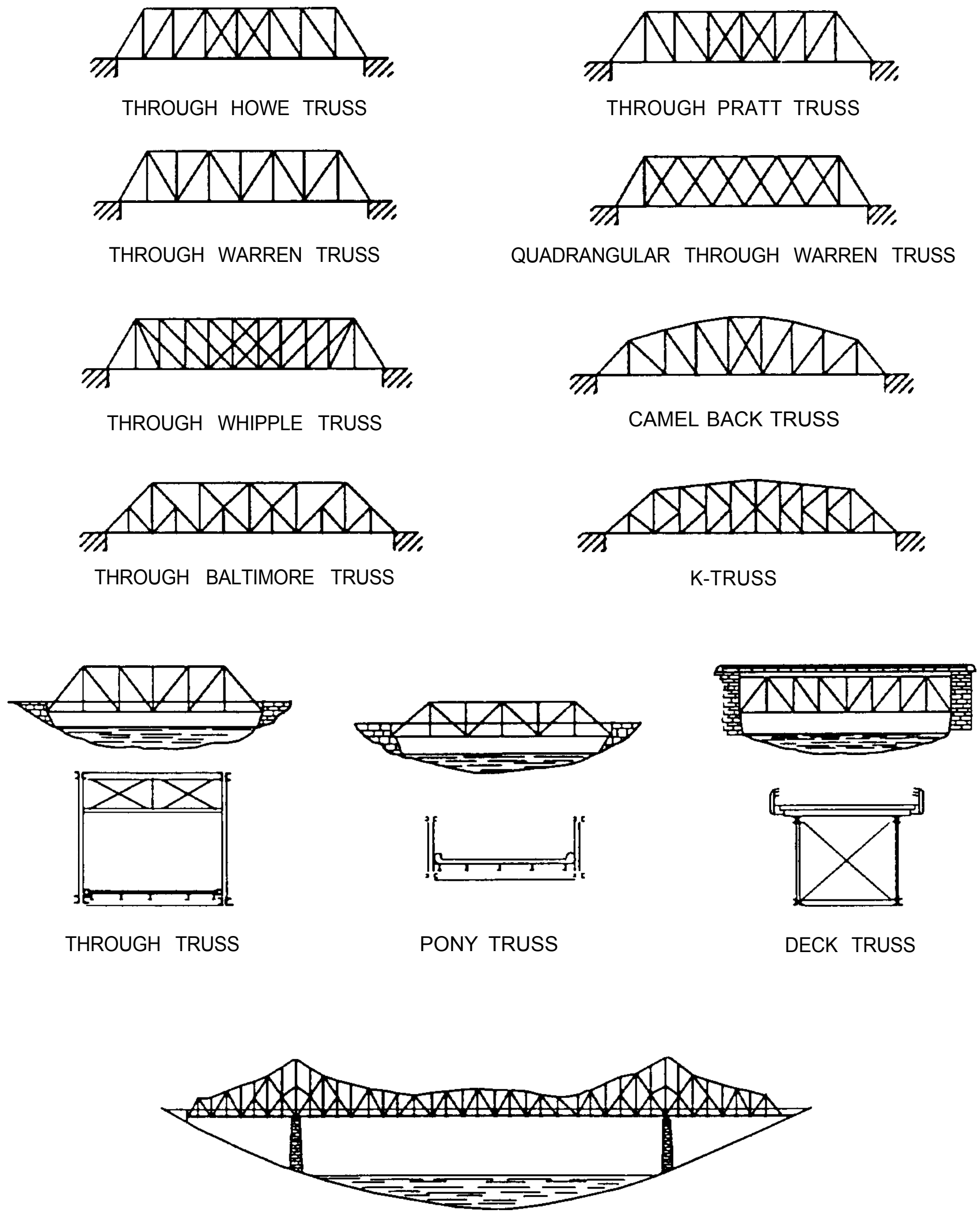


Figure 2-2. Truss bridges: steel or timber construction.

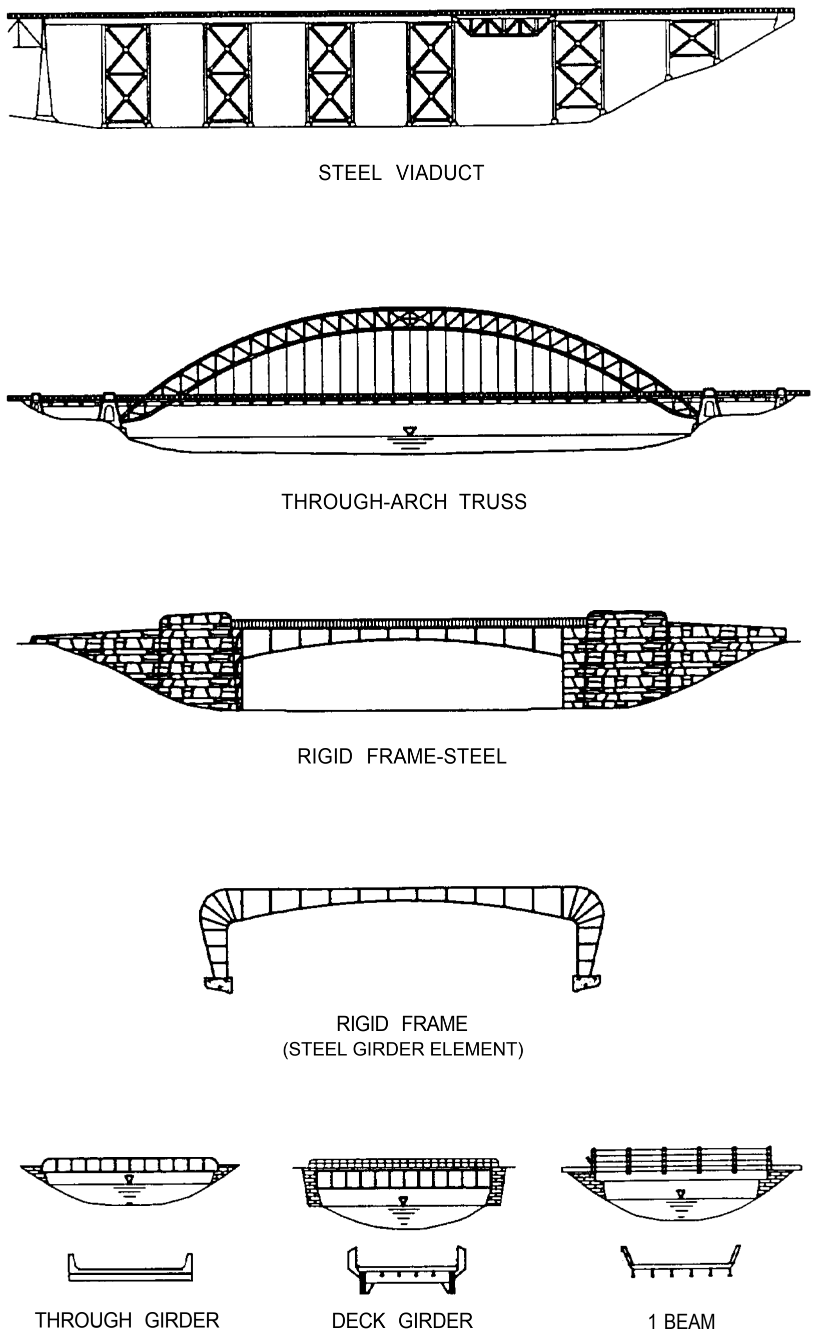


Figure 2-3. Steel bridges.

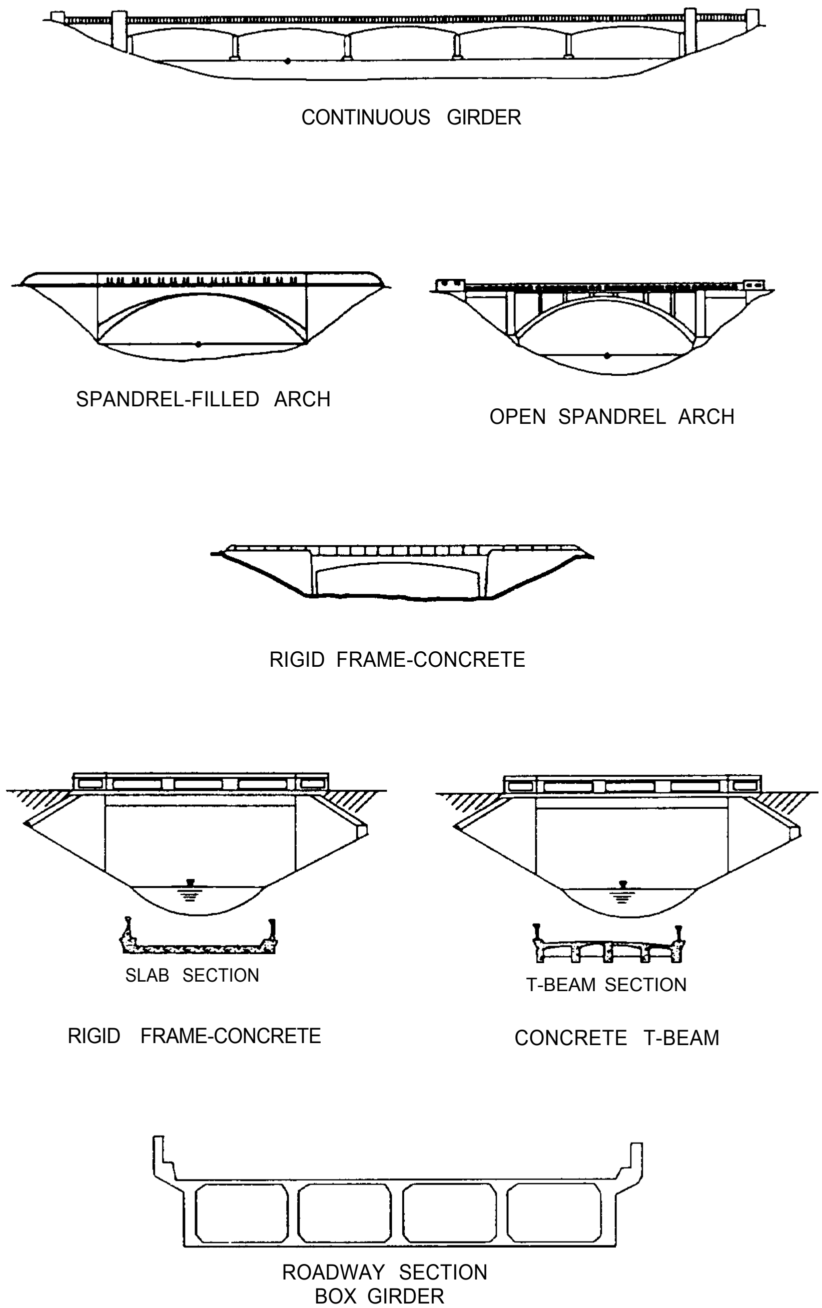


Figure 2-4. Reinforced concrete bridges.

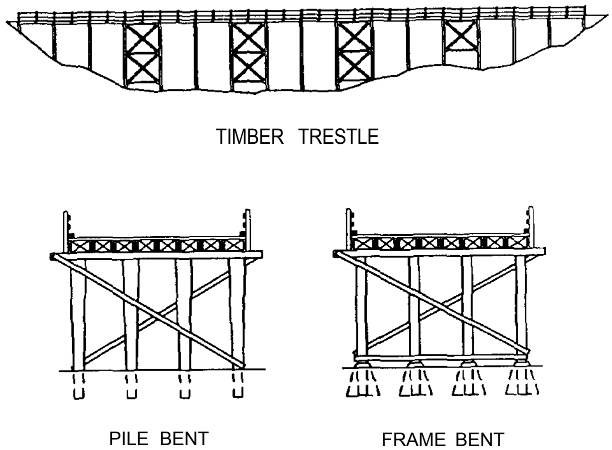


Figure 2-5. Timber bridges.

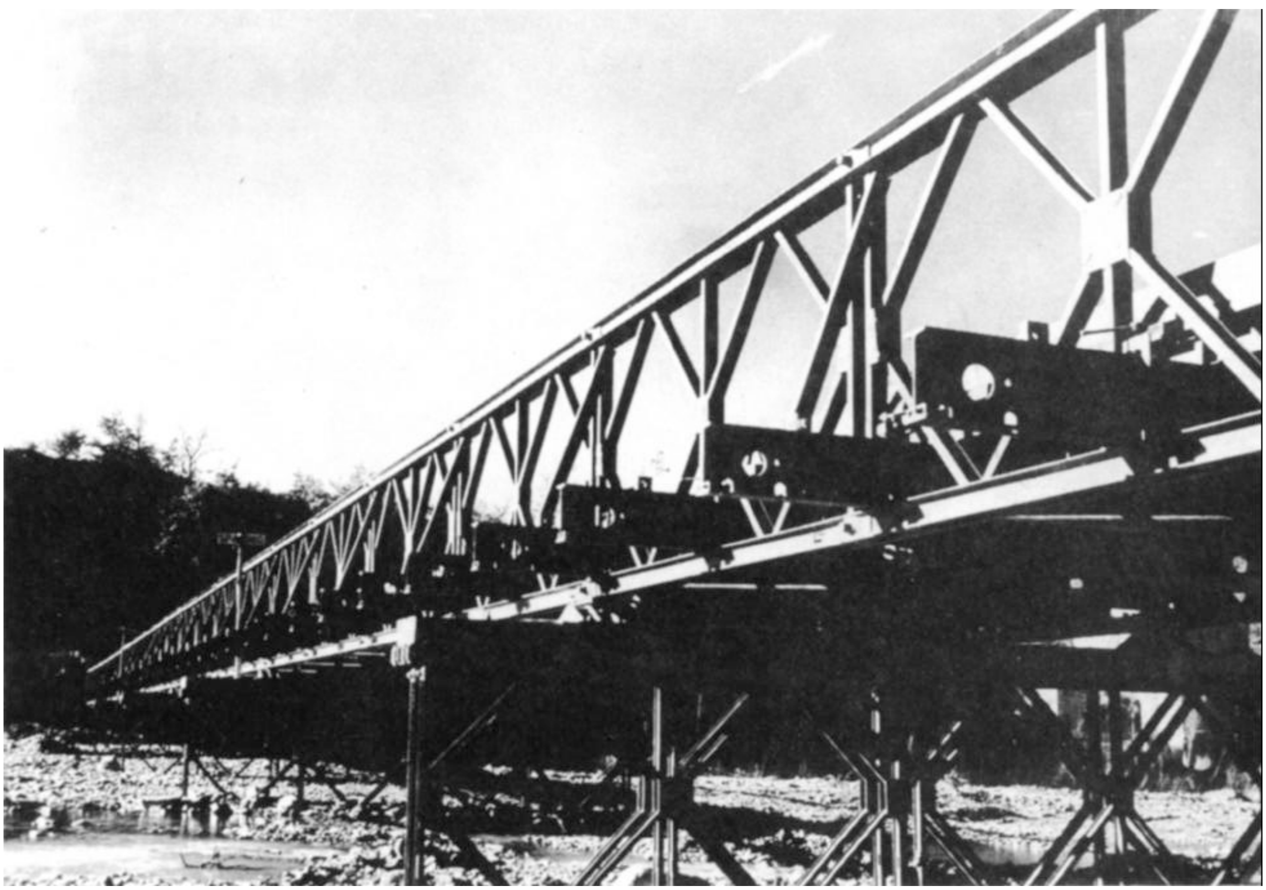


Figure 2-6. Bailey bridge using bailey panel piers.

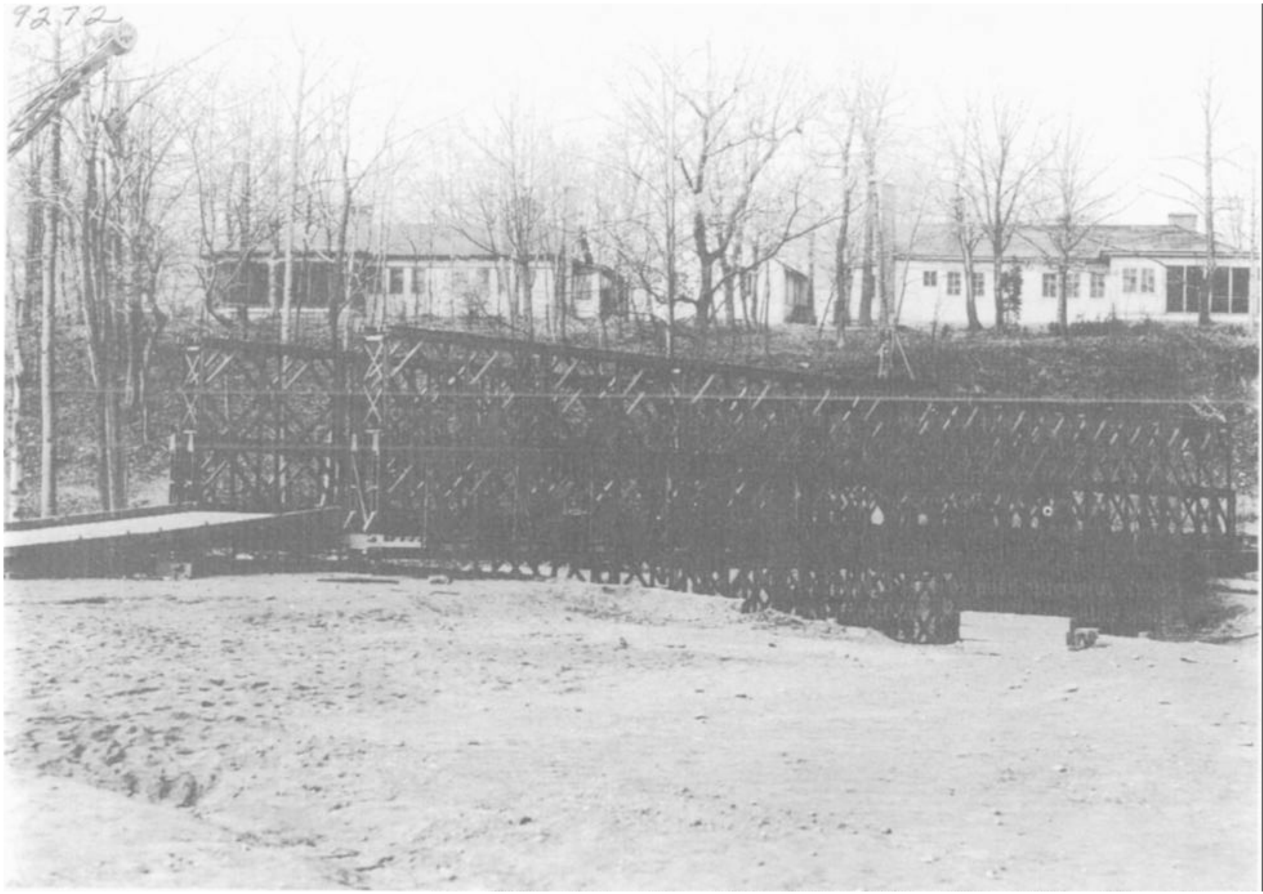


Figure 2-7. Double-double bailey bridge.

Figure 2-8. T6 aluminum fixed bridge.

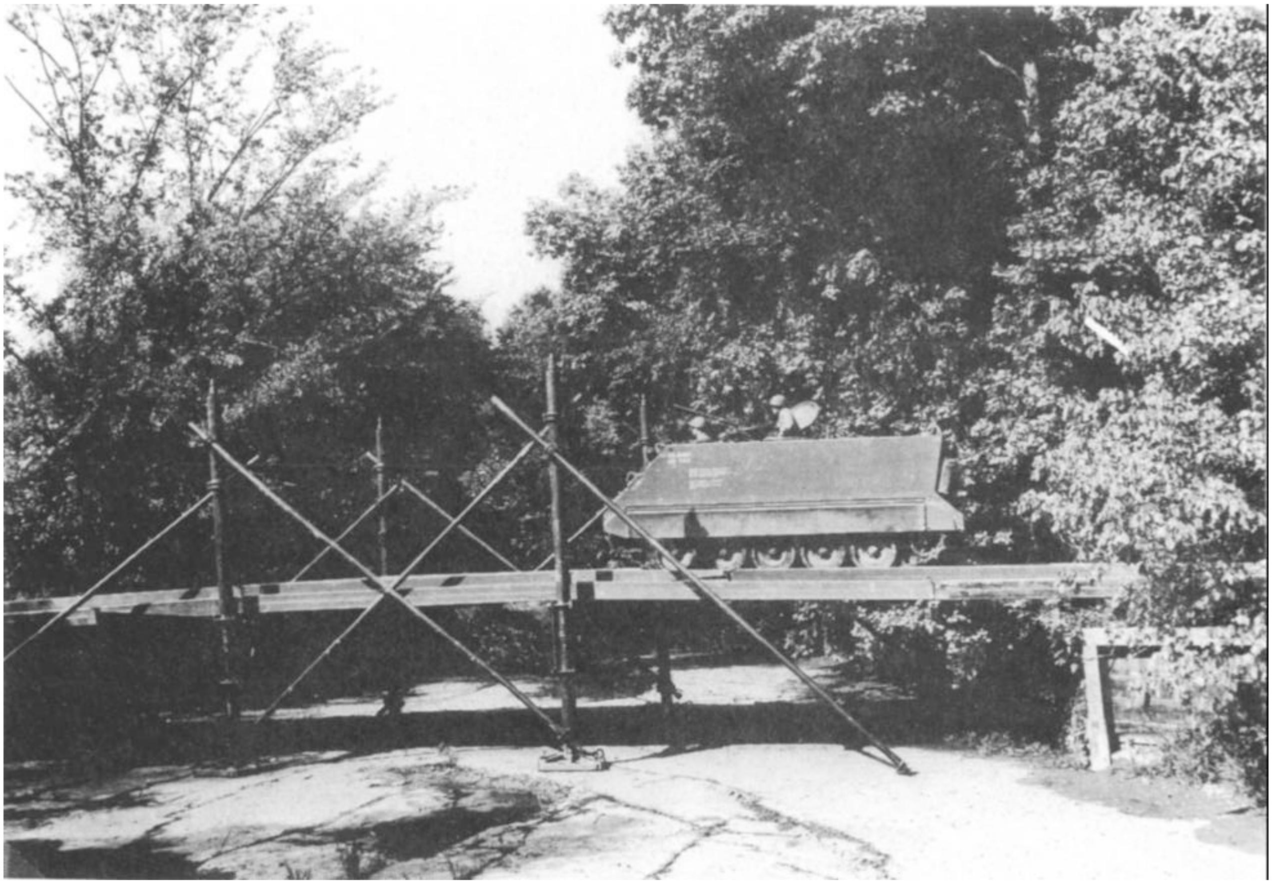


Figure 2-9. Class 50 M-4 trestle bridge, aluminum.

Figure 2-10. Timber trestle.

CHAPTER 3

BRIDGE ELEMENTS

Section I. SUBSTRUCTURE ELEMENTS

3-1. General

Typical bridge nomenclature is summarized in figure 3-1. A bridge basically consists of two main parts: the substructure and the superstructure. The substructure includes those parts which transfer the loads from the bridge span down to the supporting ground. For a single-span structure the substructure consists of two abutments, while for multispan structures there are also one or more piers. Sometimes steel bents or towers are used instead of piers. The loads are applied to the substructure through the bearing plates and transmitted through the abutment walls or pier columns to the footings. If the soil is of adequate strength, the footings will distribute the loads over a sufficiently large area. If not, the footings themselves must be supported on pile foundations extended down to a firm underlying stratum.

3-2. Abutments

Abutments are substructures supporting the end of a single-span or the extreme end of a multispan superstructure and usually retaining or supporting the approach embankment. Typical abutments are shown in figure 3-2. Abutments usually consist of a footing, a stern or breast wall, a bridge seat, a backwall, and wing walls. The backwall prevents the approach embankment soil from spilling onto the bridge seat, where bearings for the superstructure are situated. The wing walls are retainers which keep the embankment soil around the abutment from spilling into the waterway or roadway that is spanned by the bridge. When U-shaped wing walls are used, parapets and railings are often placed on top of them. Abutments may be constructed of plain concrete, reinforced concrete, stone masonry, or a combination of concrete and stone masonry. Plain concrete and stone masonry abutments are usually gravity structures, while reinforced concrete abutments are mostly cantilever or counterfort types.

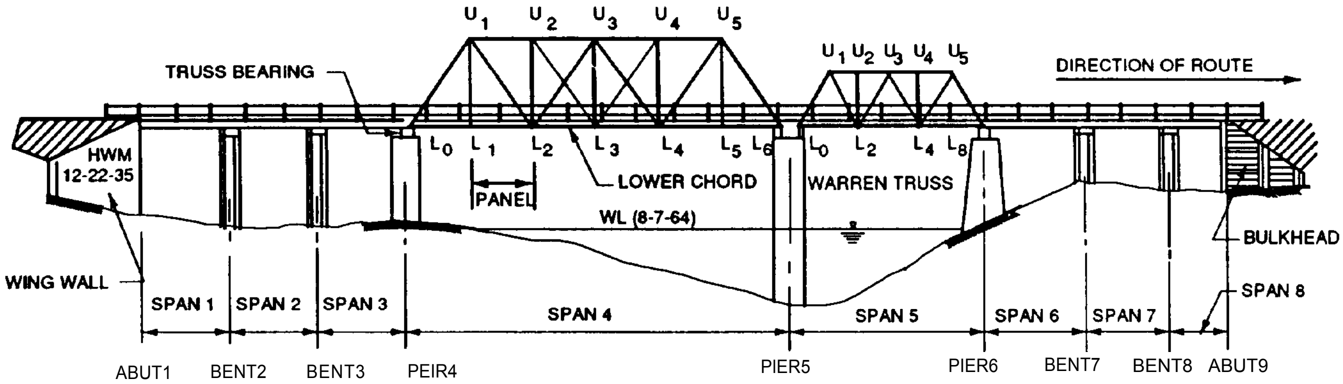
3-3. Piers and bents

Typical piers and bents are shown in figure 3-3. Piers transmit the load of the superstructure to the foundation material and provide intermediate supports between the abutments. Footings, columns or stems, and caps are the main elements of piers. The footings are slabs which transmit the load to the soil, rock, or to some other foundation unit such as piles, caissons, or drilled shafts. The columns or stems transmit vertical load and moment to the footings. The cap receives and distributes the superstructure loads. River bridges, railway bridges, and some highway underpasses are likely to use the solid wall pier. Highway grade separations of normal width often use multilegged piers, often with a cap binding the whole unit into a rigid frame. "Bents" are basically piers without footings, which consist of a row of two or more posts or piles, tied together at the top with a cap. Piers and bents may be made of timber, steel, concrete, stones, or combination of materials. Piles are used to transmit the bridge loads to the foundation material when the foundations are to be on soft soils, in deep water, or in swift streams. Typical pile types are: steel H Piles, timber, concrete piles (both CIP and precast/prestressed), and concrete filled pipe or shell piles.

Section II. SUPERSTRUCTURES

3-4. General

The superstructure includes all those parts which are supported by the substructure, with the main part being the bridge spans. Vehicular forces are transmitted from the bridge deck, through the supporting beams or girders of the span, and into the substructure. The reinforced concrete slab bridge has the simplest type of superstructure since the slab carries the load of the vehicle directly to the abutment or piers. On beam or girder bridges, the slab is supported on longitudinal steel, concrete, or timber members which, in turn, carry the load to the abutment or piers. Some superstructures consist of the deck, a floor system, and two or more main supporting members. Figure 3-4 shows several different types of superstructures and their associated elements. The components of superstructures are summarized in the following paragraphs.



ABBREVIATIONS

CDF CREOSOTED DOUGLAS FIR (PRESSURE TREATED)
WS WEARING SURFACE
WL WATER LEVEL
HWM HIGH WATER MARK
RC REINFORCED CONCRETE
RW REDWOOD
UF UNTREATED FIR
BTF BRUSHED TREATED FIR (WOOD PRESERVATIVE)
VC VERTICAL CLEARANCE
b b DISTANCE BACK TO BACK
b b DISTANCE BACK TO BACK

Figure 3-1. Bridge nomenclature.

3-5. Decks

The deck is that portion of a bridge which provides direct support for vehicular and pedestrian traffic. The deck may be a reinforced concrete slab, timber flooring, or a steel plate or grating on the top surface of abutting concrete members or units. While normally distributing load to a system of beams and stringers, a deck may also be the main supporting element of a bridge, as with a reinforced concrete slab structure or a laminated bridge. The "wearing course" of a deck provides the riding surface for the traffic and is placed on top of the structural portion of the deck. There are also wearing courses poured integral with the structural slab, and then the deck is referred to as a monolithic deck.

3-6. Floor systems

The floor system may consist of closely spaced transverse floor beams between girders (refer to the deck girder bridge in figure 3-4, sheet 2, part c) or several longitudinal stringers carried by transverse floor beams (refer to the through girder of figure 3-4, sheet 2, part c). In floors of this type, the stringers are usually wide flange beams while the floor beams may be plate girders, wide flange beams, or trusses. Where floor beams only are used, they may be rolled beams or plate girders. Several floor systems are shown in figure 3-5.

3-7. Main supporting members

The main supporting members transmit all loads from the floor system to the supports at points on the piers and abutments. The strength and safety of the bridge structure depends primarily on the main supporting members. These members may be timber, steel, or concrete beams; steel plate girders; timber or steel trusses or concrete rigid frames; arches of various material; or steel cables. The most general types of these members are discussed as follows:

a. Rolled beams. The rolled beam is used for short spans. It comes from the rolling mill as an integral unit composed of two flanges and a web. The flanges resist the bending moment and the web resists shear. The more common types of rolled beam shapes are shown in figure 3-6.

b. Plate (built-up) girders. This type of structural member is used for intermediate span lengths not requiring a truss and yet requiring a member larger than a rolled beam. The basic elements of a plate girder are a web to which flanges are riveted or welded at the top and bottom edges. The most common forms of cross section are shown in figure 3-7. The component parts of a plate girder are as follows (figure 3-7):

(1) *Flange angles.* These are used for riveted plate girders and carry tensile or compressive forces induced by bending.

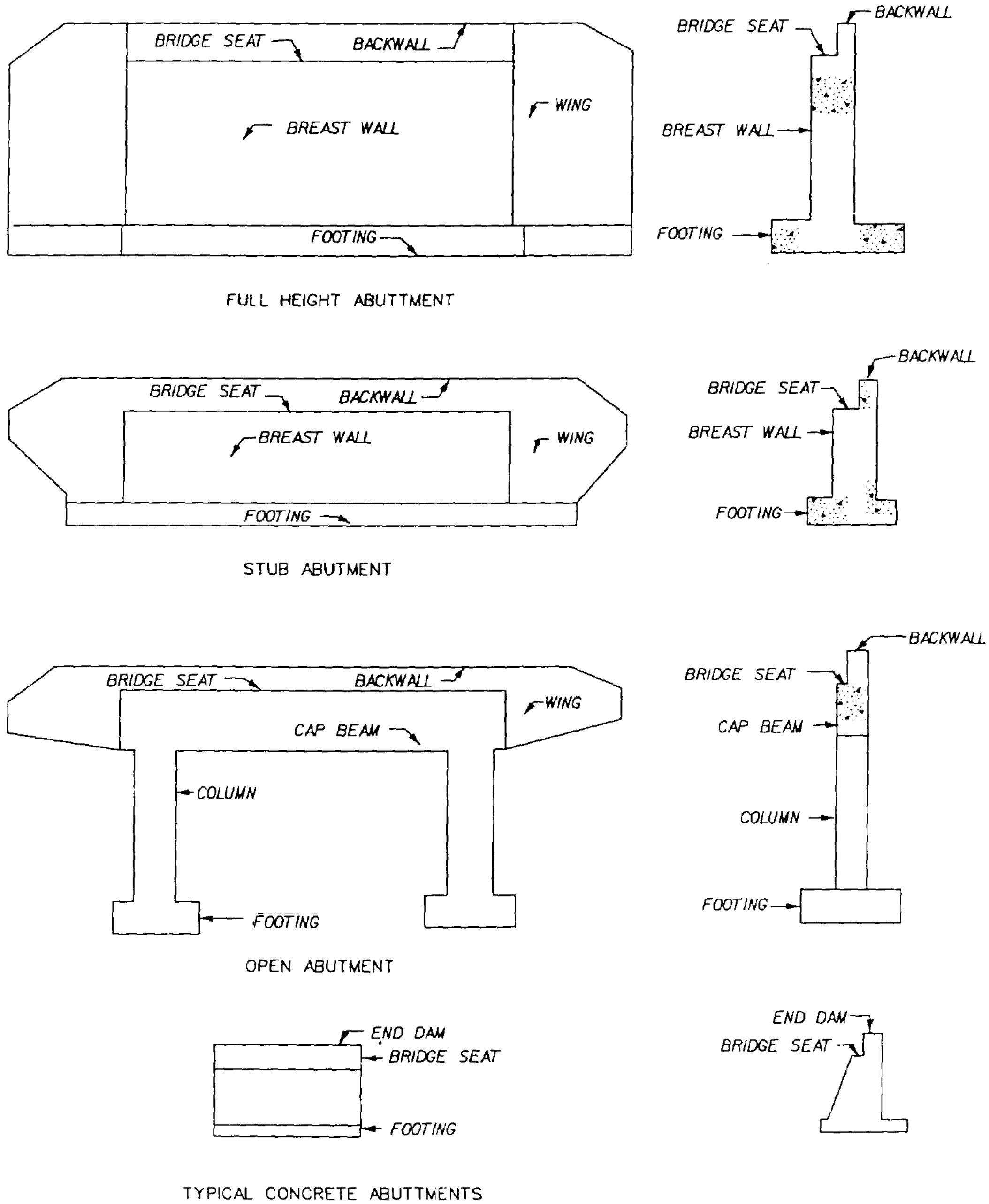


Figure 3-2. Typical abutments

(2) *Cover plates.* These are welded or riveted to the top and/or bottom flanges of the girder to increase the load carrying capacity.

(3) *Bearing stiffeners.* These are plates or angles placed vertically at the locations of the support and attached to the web. Their primary function is to transmit the shearing stresses in the web plate to the bearing device and, by so doing, prevent web crippling and buckling.

(4) *Intermediate stiffeners.* These are used at points of concentrated loads or for deep girder to prevent web crippling and buckling.

c. Concrete beams. These beams are usually reinforced wherein the tensile stresses, whether resulting from bending, shear, or combinations thereof produced by live and dead loadings, are by design carried by the metal reinforcement. The concrete takes compression (and some shear) only. It is commonly rectangular or tee-shaped with its depth dimension greater than its stem width.

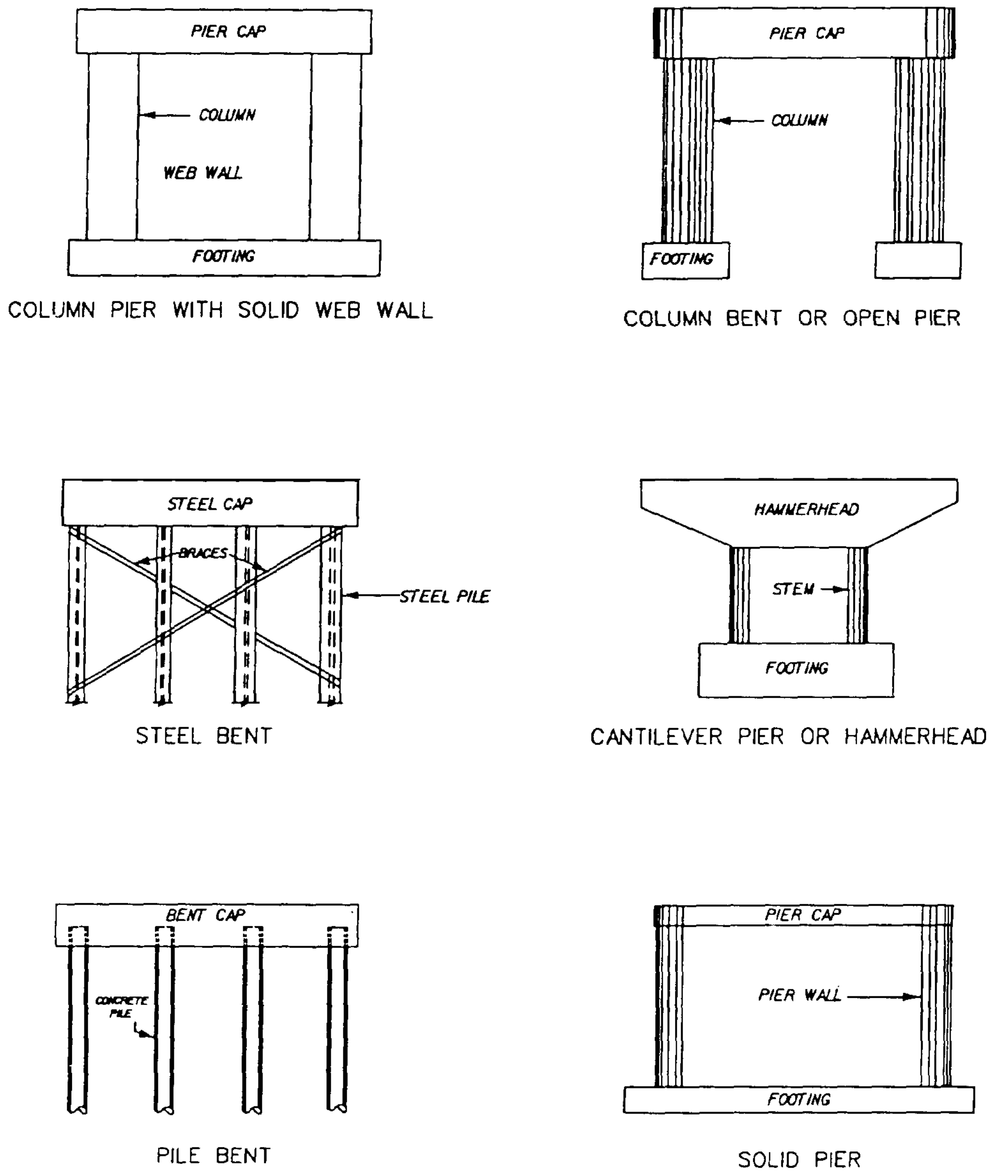
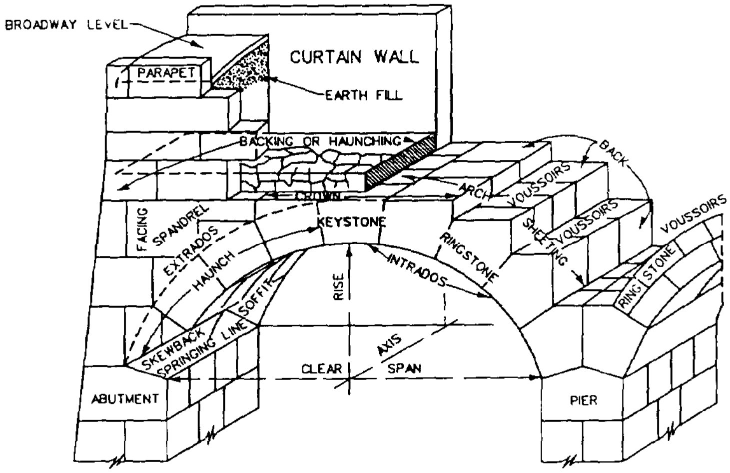
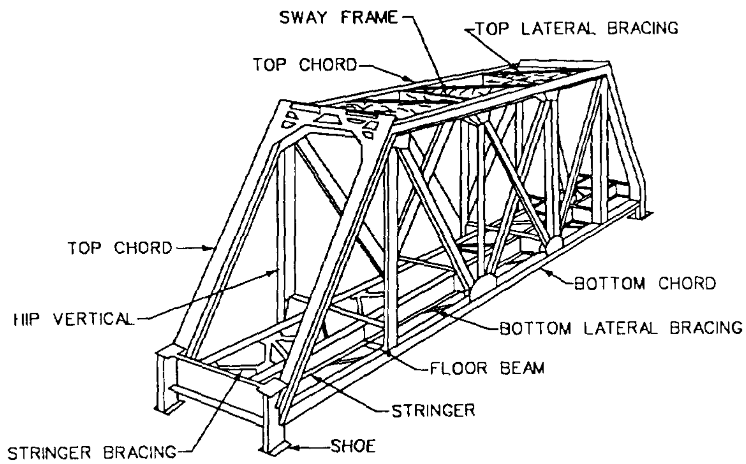


Figure 3-3. Typical piers and bents.

d. Trusses. The truss is one form of structural system which, because of its characteristics, provides high load-carrying capacities and can be used to span greater lengths than rolled beams and girders. The truss functions basically in the same manner as a rolled beam or girder in resisting loads, with the top and bottom chords acting as the flange and the beam and the diagonal members acting as the web. While most trusses are of steel, timber trusses also exist. Truss members may be connected with rivets, bolts, or pins. Although the configuration of trusses varies widely, the essential components are common to all. Truss members may be built-up sections, rolled sections, tubing, pipe, eye-bars, or solid rods. An earlier commonly used construction practice was to connect channels by lacing bars and stay plates at the ends. Interior verticals and diagonals on old bridges may consist of relatively slender solid rods when the member is subject only to tension. When two opposing tension diagonals are provided in the panel of a truss, they are termed "counters." The basic parts of a truss are summarized in figures 3-1, 3-4 (sheet 1, part b) and 3-8. They are discussed as follows:

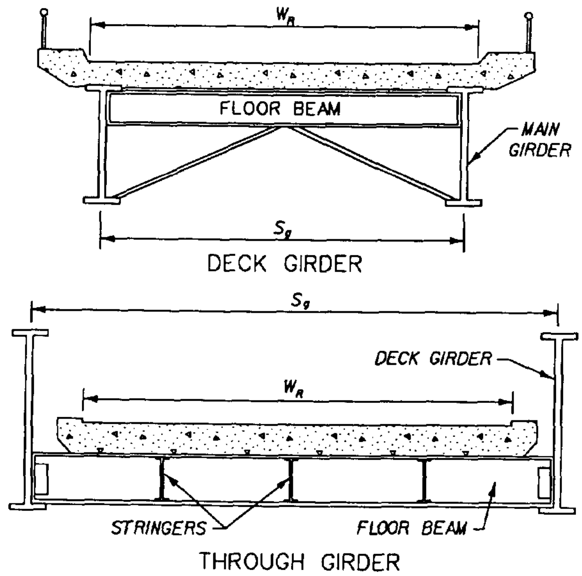


A. MASONRY ARCH BRIDGE.

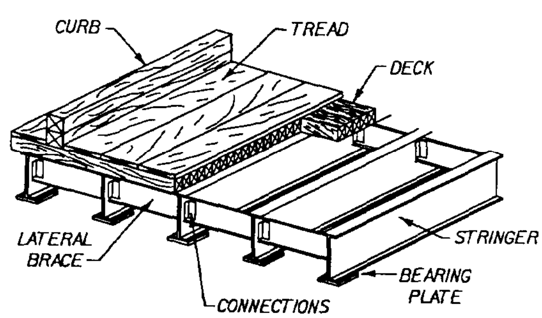


B. TRUSS

Figure 3-4. Typical superstructures. (Sheet 1 of 2)



c. GIRDER BRIDGE



d. STEEL STRINGER BRIDGE

Figure 3-4. Typical superstructures. (Sheet 2 of 2)

(1) *Chord.* In a truss, the upper and the lower longitudinal members extending the full span length are called chords. The upper portion is designated as the upper or top chord and correspondingly lower portion is designated as the lower or bottom chord. For simple span, the top chord will always be in compression, and the bottom chord will always be in tension and should be considered a main structural member. Failure of either chord will render the truss unsafe.

(2) *Diagonals.* The diagonal web members span between successive top and bottom chords and will resist tension or compression, depending on the truss configuration. Most diagonals are also main structural members and their failure would be extremely critical and render the truss unsafe.

(3) *Verticals.* Vertical web members span between top and bottom chords, which will resist tension or compression stresses depending upon the truss configuration. Most verticals are a main structural member, and their failure would usually be critical and render the truss unsafe.

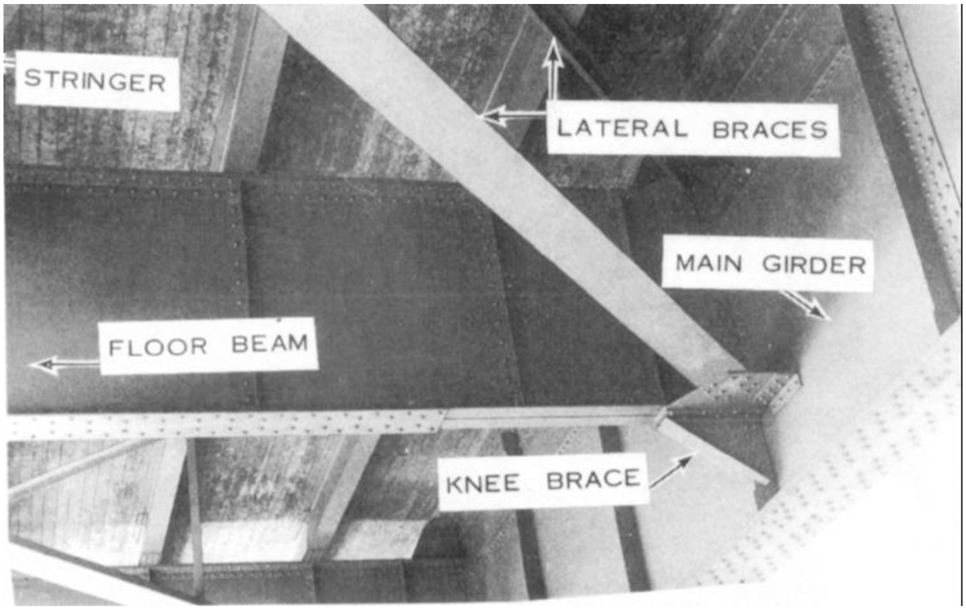


Figure 3-5. Typical floor systems. (Sheet 1 of 3)

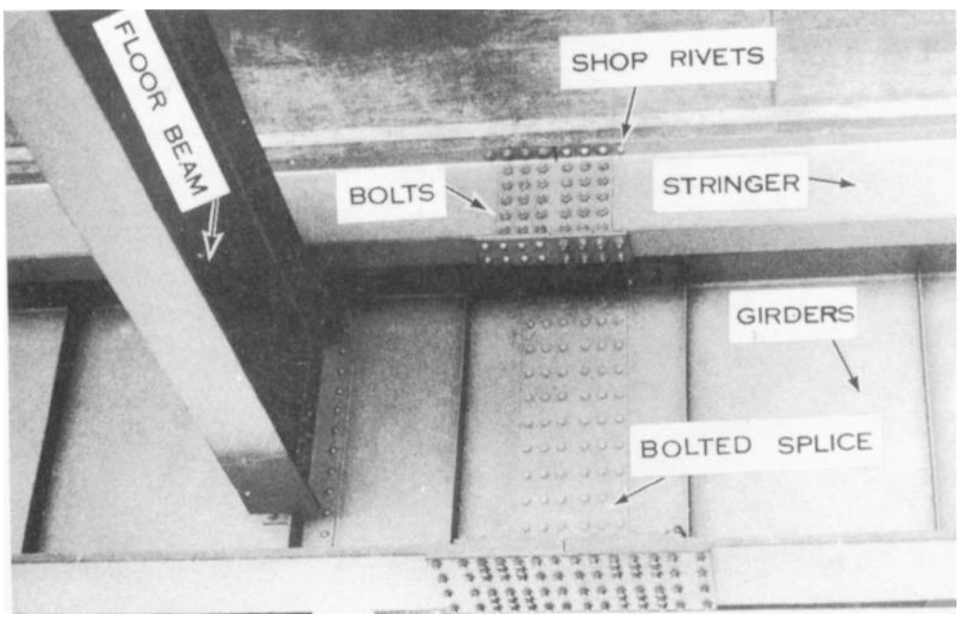


Figure 3-5. Typical floor systems. (Sheet 2 of 3)

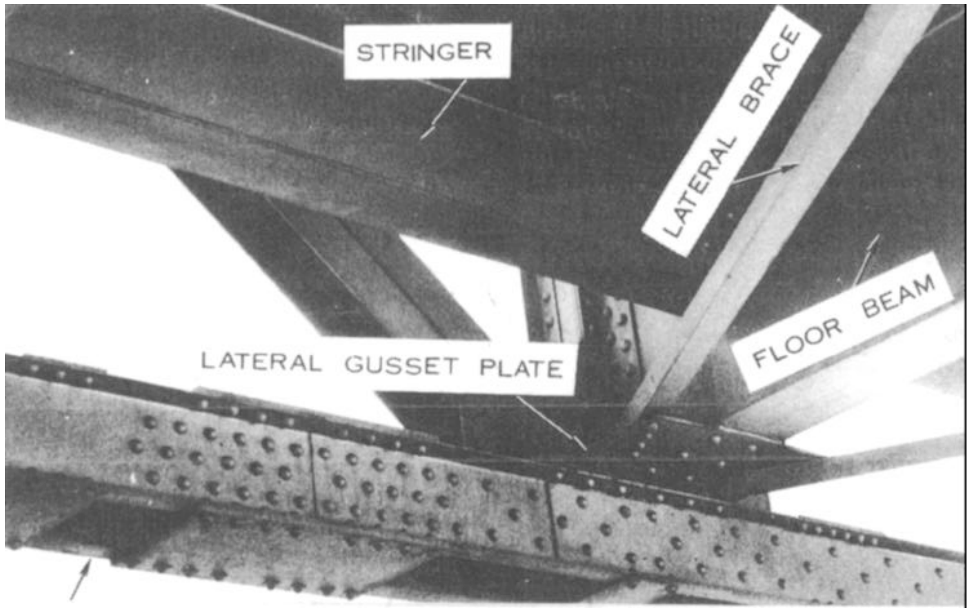


Figure 3-5. Typical floor systems. (Sheet 3 of 3)

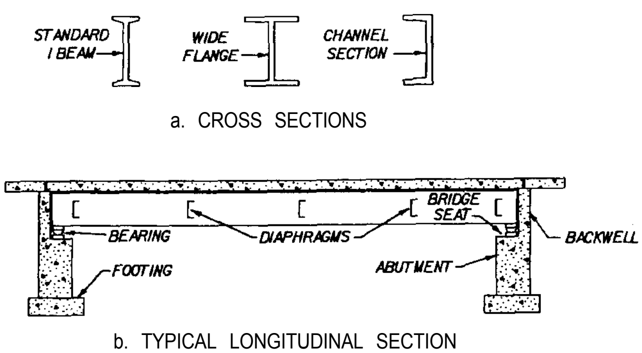


Figure 3-6. Rolled steel beams.

(4) *Panel point.* The panel point is the point of intersection of primary web and chord members of a truss. Note: Items 5 through 11 can be considered secondary structural members and although their failure should receive immediate attention, an individual member failure will not render the structure unsafe.

(5) *Portal bracing.* The portal bracing is found overhead at the end of a through truss and provides lateral stability and shear transfer between trusses.

(6) *Sway bracing.* This bracing spans between the trusses at interior panel points and provides lateral stability and shear transfer between trusses.

(7) *Top lateral bracing.* The top lateral braces lie in the plane of the top chord and provide lateral stability between the two trusses and resistance to wing stress.

(8) *Bottom lateral bracing. These* braces lie in the plane of the bottom chord and provide lateral stability and resistance to wind stresses.

(9) *Floor beam.* The floor beam spans between trusses at the panel points and carries loads from the floor stringer and deck system to the trusses.

(10) *Stringers.* These span between floor beams and provide the primary support for the deck system. The deck loading is transmitted to the stringers and through the stringers to the floor beams and to the truss.

(11) *Gusset plates.* These plates connect the structural members of a truss. On older trusses, pins are used instead of gussets.

3-8. Bracing

The individual members of beam and girder structures are tied together with diaphragms and cross frames; trusses are tied together with portals, cross frames, and sway bracing. Diaphragms and cross frames stabilize the beams or trusses and distribute loads between them (figure 3-9). A diaphragm is usually a solid web member, either of a rolled shape or built up, while a cross frame is a truss, panel, or frame. Since portals and sway braces help maintain the cross section of the bridge, they are positioned as deep as clearance requirements permit. Portals usually are in the plane of the end posts and carry lateral forces from the top chord bracing to the supports (figure 3-8, sheet 1). Lateral bracing placed at the upper or lower chords (or flanges), or at both levels, transmits lateral forces (such as wind) to the supports (figures 3-8 (sheet 3), 3-8 (sheet 4), and 3-9).

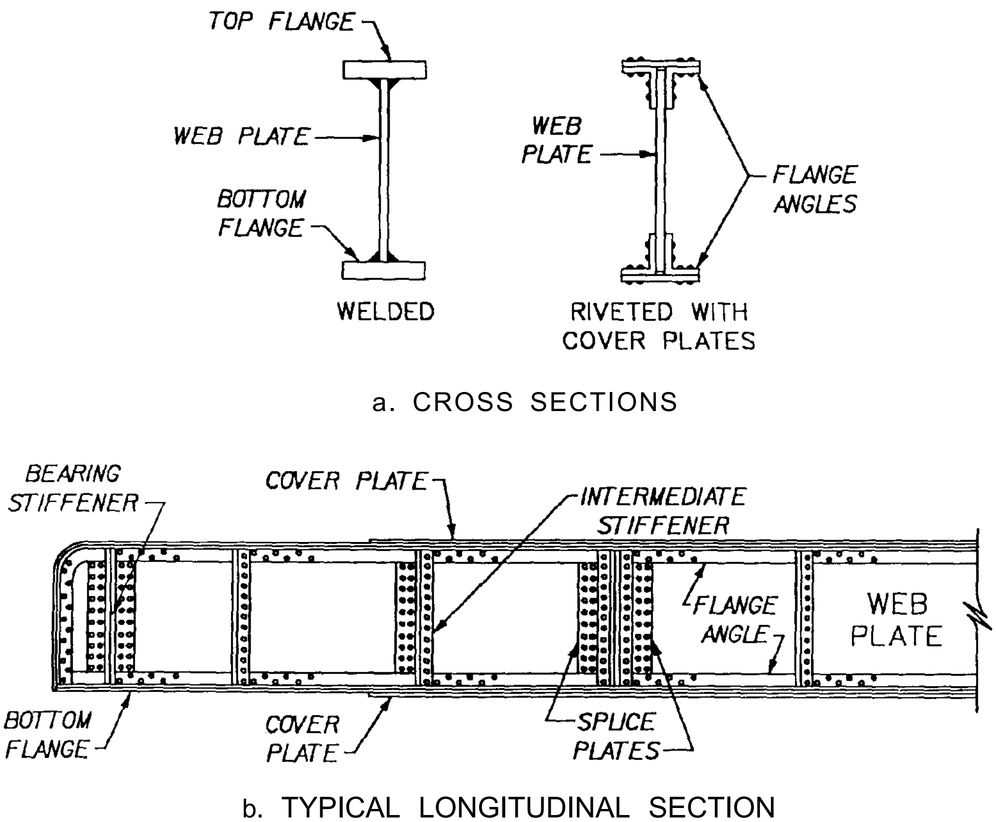


Figure 3-7. Plate girders.

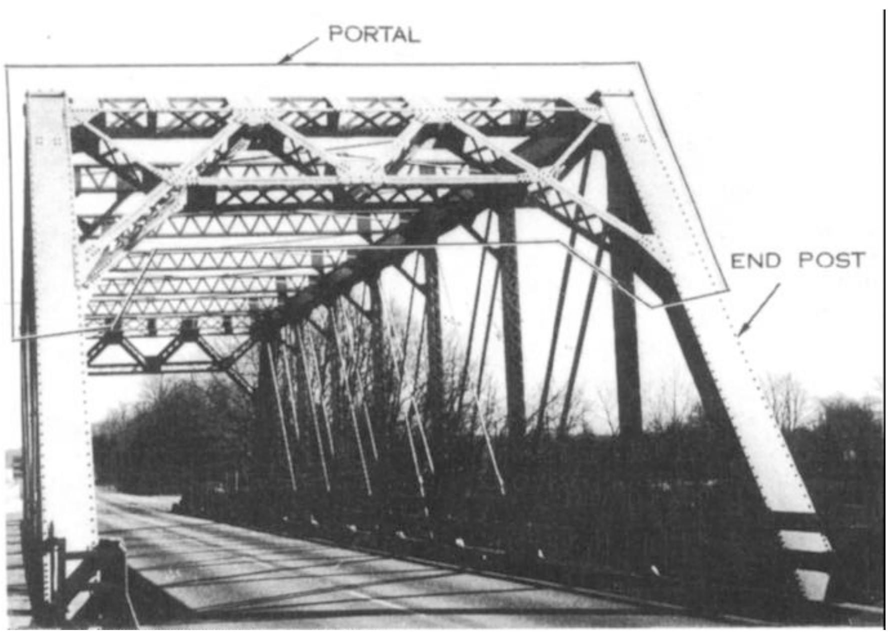


Figure 3-8. Truss components. (Sheet 1 of 5)

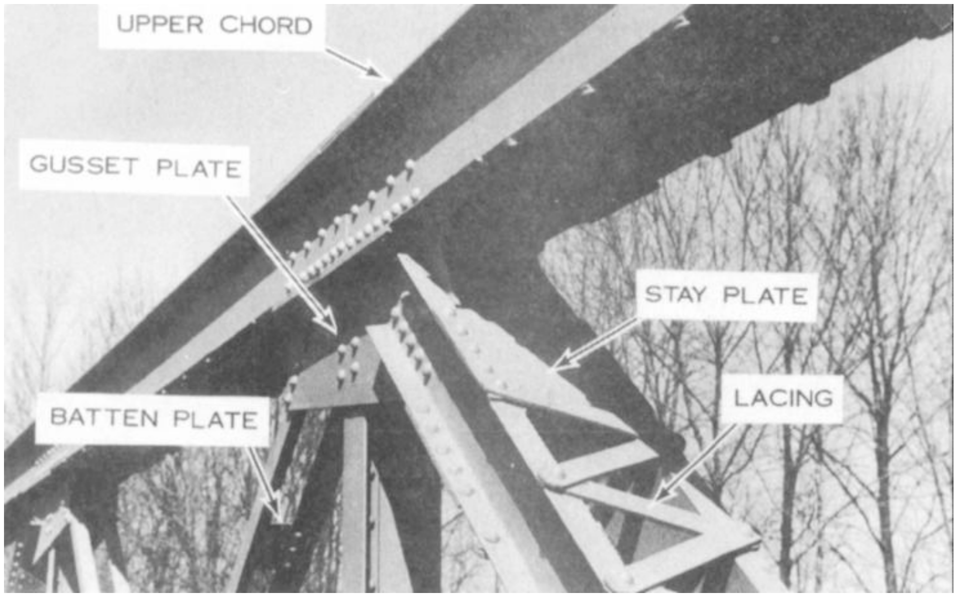


Figure 3-8. Truss components. (Sheet 2 of 5)

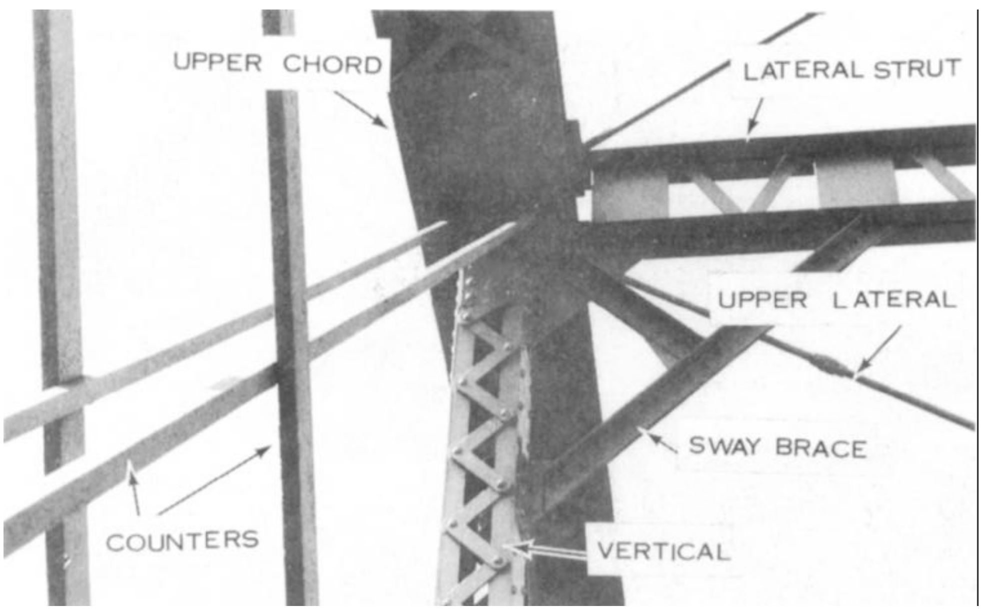


Figure 3-8. Truss components. (Sheet 3 of 5)

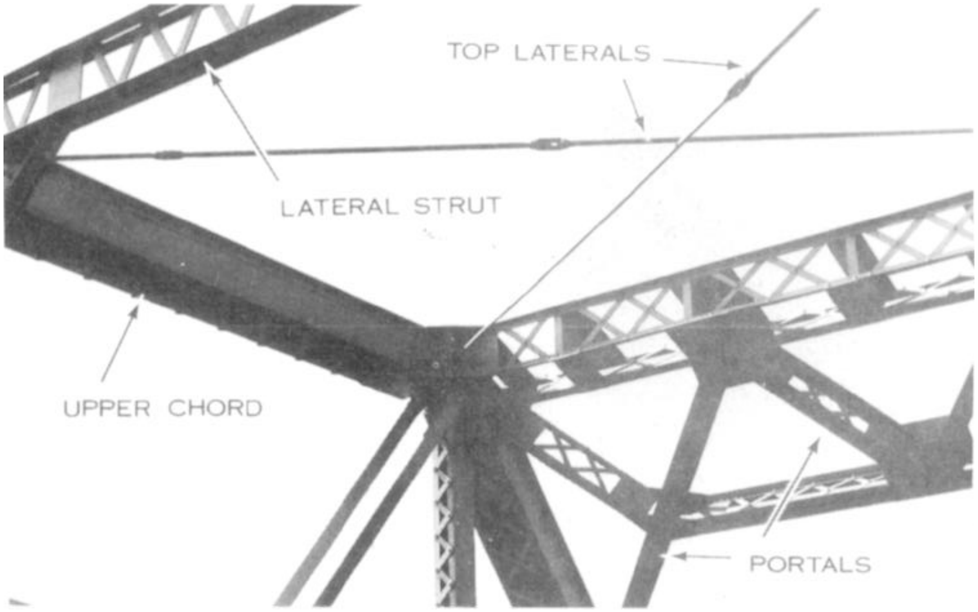


Figure 3-8. Truss components. Sheet 4 of 5)

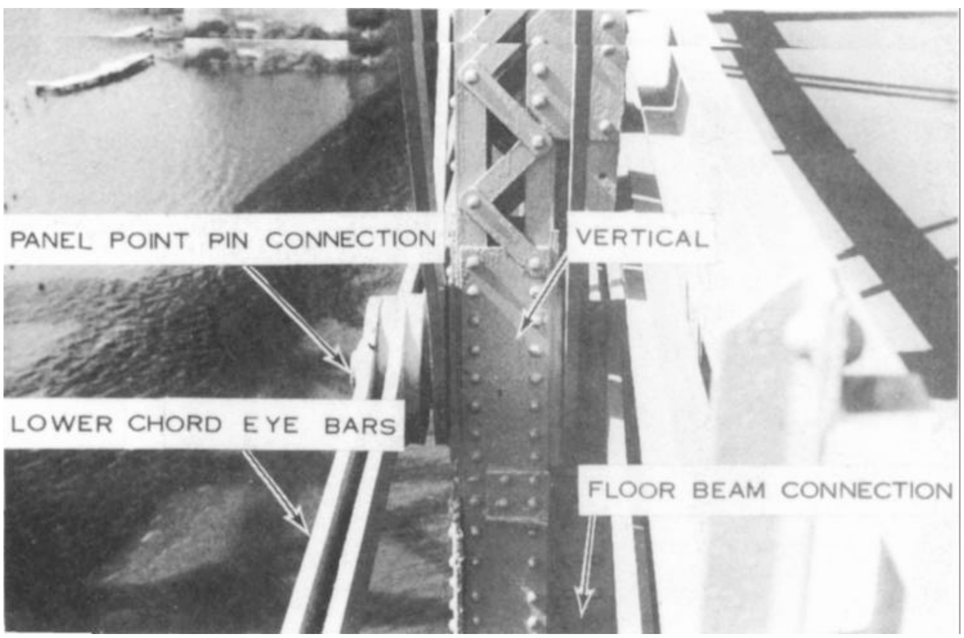


Figure 3-8. Truss components. (Sheet 5 of 5)

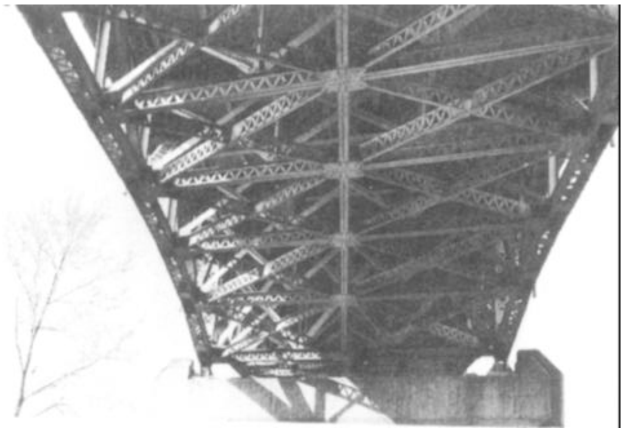


Figure 3-9. Bracing. (Sheet 1 of 2)

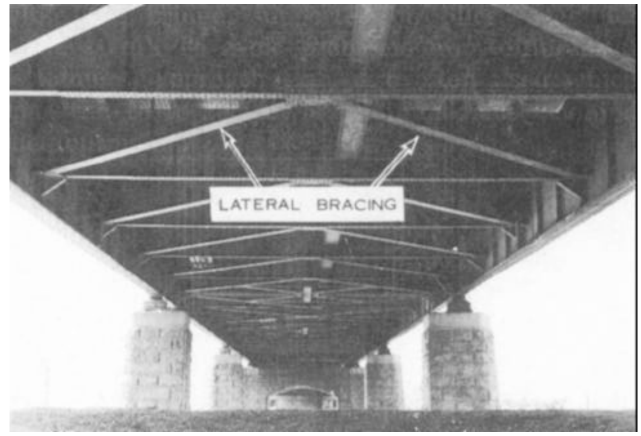


Figure 3-9. Bracing. (Sheet 2 of 2)

Section III. MISCELLANEOUS ELEMENTS

3-9. Bearings

Bearings transmit and distribute the superstructure loads to the substructure, and they permit the superstructure to undergo necessary movements without developing harmful overstresses. They are vitally important to the functioning of the structure. If they are not kept in good working order, very high stresses may be induced in the structure that could shorten the usable life of the structure. Bearings are of two general types, fixed and expansion. Fixed bearings resist lateral and longitudinal movement of the superstructure but permit rotation. Expansion bearings allow longitudinal movement to account for expansion and contraction of the superstructure. Depending on structural requirements, the bearings may or may not be designed to resist vertical uplift. Bearings are metal or elastomeric. Typical metal bearings are shown in figures 3-10 and 3-11. Elastomeric bearing pads (figure 3-12) have become a popular choice for use as expansion bearings. They are made of a rubber-like material or elastomer molded in rectangular pads, or in strips. Note that bearings can also be used to support suspended spans as shown in figure 3-13.

3-10. Pin and hanger supports

These are devices used to attach a suspended section to a cantilevered section (figure 3-14). These connections may be free or fixed at one end as shown in figures 3-15 and 3-16.

3-11. Expansion joints

Since all materials expand and contract with changes in temperature, provisions must be made in the bridge superstructure to permit movement to take place without damage to the bridge. On very short superstructures, there is usually sufficient yielding in the foundation to allow the small amount of movement to occur without difficulty. On longer structures, however, specifically designed expansion joints are provided in the deck. Where only moderate amounts of movements are expected, the joint may be only an opening between abutting parts. When a watertight seal is desired, a premolded filler topped with a poured-in-place sealer or a preformed compression seal is inserted (figure 3-17, sheet 1). Where traffic is heavy, the unprotected edge of the joint is usually armored with steel angels set in the concrete. When larger movements must be accommodated, a sliding plate or finger plate expansion joint may be used (figure 3-17, sheet 2). A trough is often provided beneath a finger plate expansion joint to catch water from the roadway.

3-12. Approaches

The approach provides a smooth transition between the roadway pavement and the bridge deck. This is important because it reduces impact forces acting on the bridge. Rough approaches are usually the result of a volume change either from settlement in the backfill material or from a general consolidation of subsoil and approach fills, while the bridge, supported on piles, does not settle at all. To avoid problems from differential settlement, approach slabs are often used which span the 15 to 25 feet of fill immediately behind the abutments.

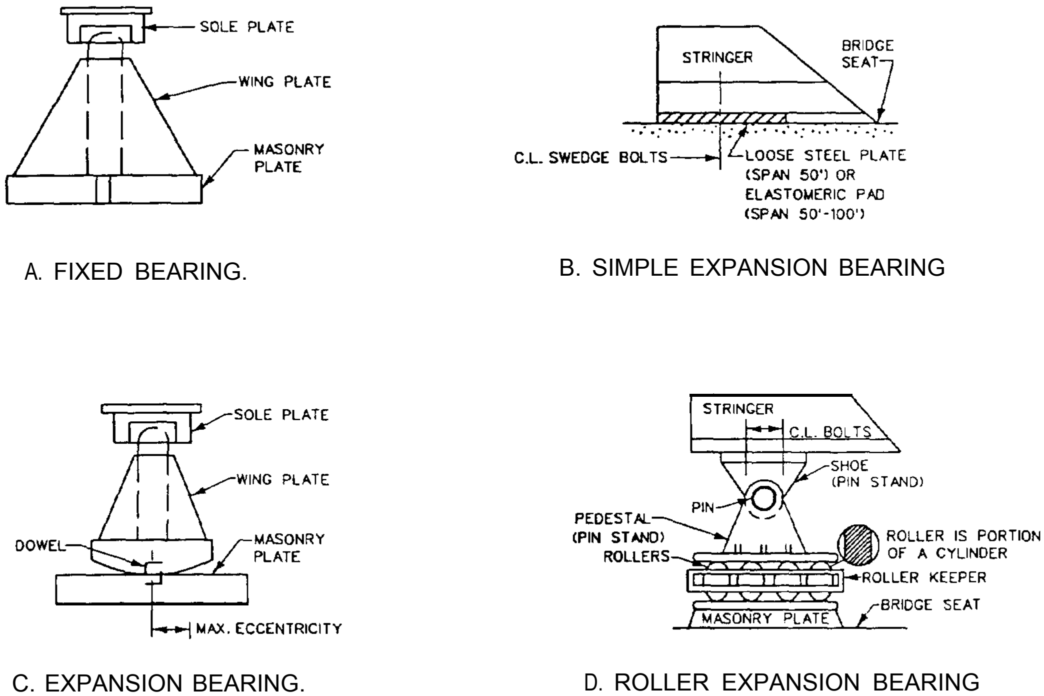


Figure 3-10. Metal bearing types.

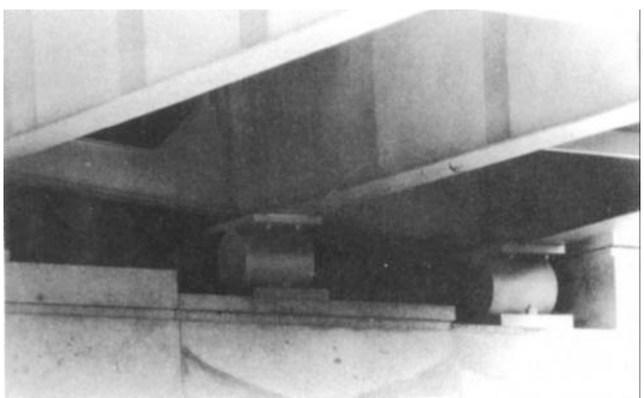


Figure 3-11. Metal bearings. (Sheet 1 of 4)

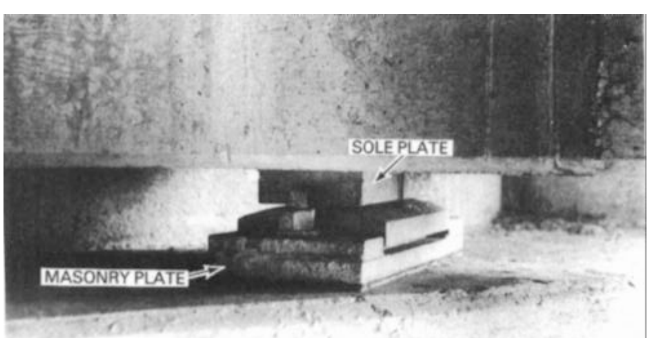


Figure 3-11. Metal bearings. (Sheet 2 of 4)

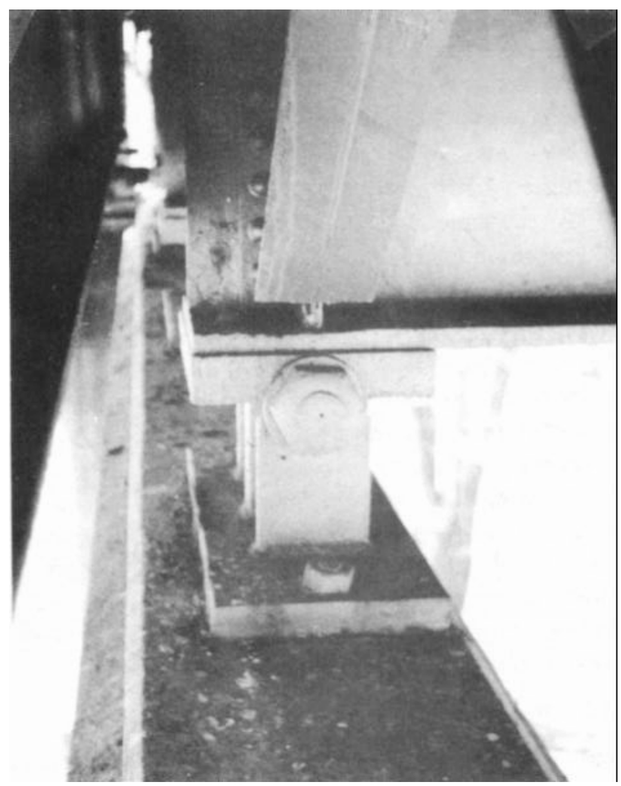


Figure 3-11. Metal bearings. (Sheet 3 of 4)

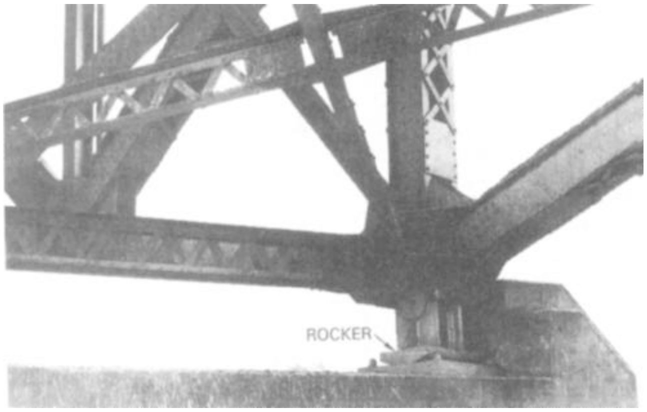


Figure 3-11. Metal bearings. (Sheet 4 of 4)

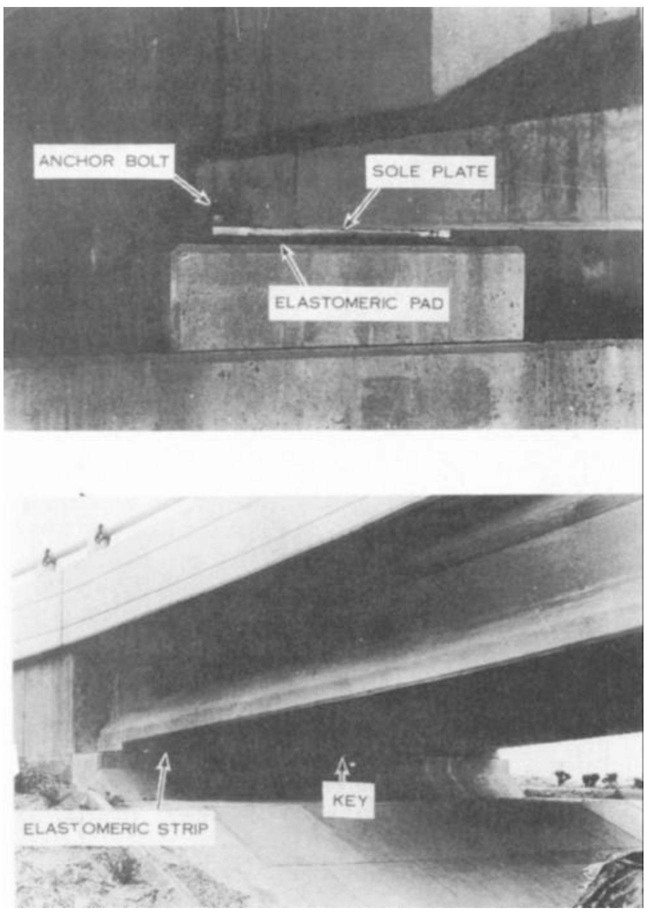


Figure 3-12. Elastomeric bearings.

3-13. Railings, sidewalks, and curbs

a. Railings. Railings should be sufficiently strong to prevent an out-of-control vehicle from going off the bridge. However, many existing bridges have vehicle guard rails that are little better than pedestrian handrails. Such guard rails are inadequate for safety, are easily damaged by vehicles, and are susceptible to deterioration. On

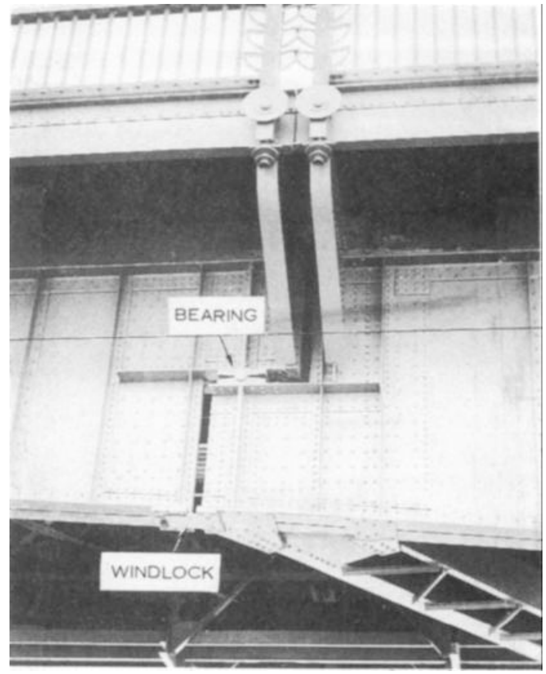


Figure 3-13. Bearing support for a suspended span.

the other hand, an unyielding guard rail poses a hazard to vehicular traffic particularly if struck head on. Unprotected parapets pose a similar danger.

b. Sidewalks. Sidewalks are provided to protect pedestrians crossing the bridge.

c. Curbs. A curb is a stone, concrete, or wooden barrier paralleling the side unit of the roadway to guide the movement of vehicle wheels and safeguard bridge trusses, railings, or other constructions existing outside of the roadway unit and also pedestrian traffic upon sidewalks from collision with vehicles and their loads.

3-14. Deck drains

Bridge drainage is very important since trapped or ponded water, especially in colder climates, can cause a great deal of damage to a bridge and is a safety hazard. Therefore, an effective system of drainage that carries the water away as quickly as possible is essential to the proper maintenance of the bridge.

3-15. Utilities

It is common for commercial and industrial utilities to use highway rights-of-way and/or adjacent areas to provide goods and services to the public. This means that some utility operations will be found on a number of bridge structures. These operations may be one or more of the following: gas, electricity, water, telephone, sewage, and liquid fuels. Utility companies perform most of their

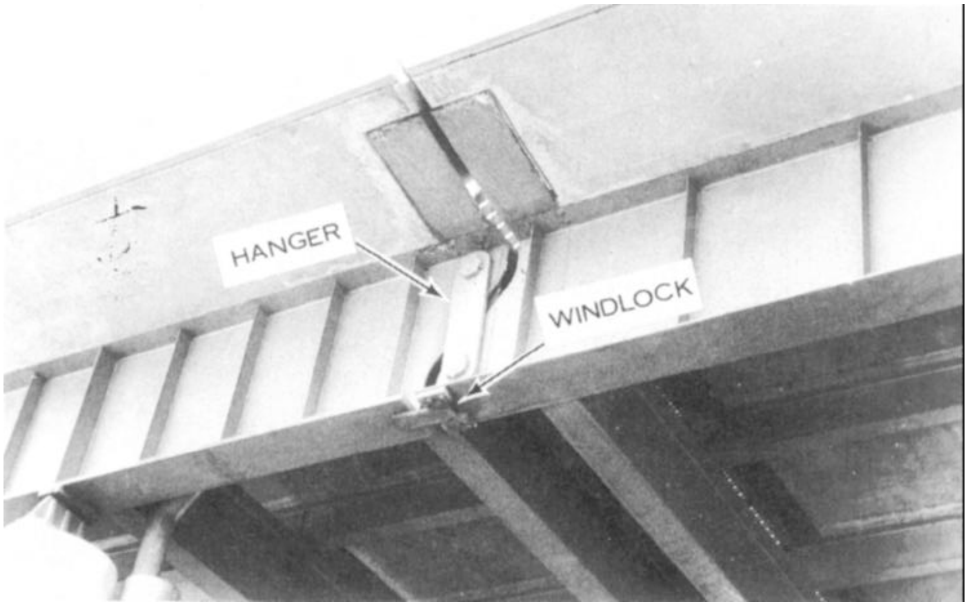


Figure 3-14. Pin and hanger connection.

facilities installation and most of the required maintenance. While the large commercial enterprises, e.g., gas, light, and telephone companies, will usually perform the scheduled maintenance of their facilities, some of the smaller publicly owned utilities, e.g., water companies, are less likely to perform adequate maintenance since they may not be as well staffed. Most utility lines or pipes are suspended from bridges between the beams or behind the fascia. On older bridges, water pipes and sewer pipes may be installed along the sides of the bridge or may be suspended under the bridge.

3-16. Lighting

Lighting on bridges will consist of "whiteway" lighting, sign lights, traffic control lights, navigation lights, and aerial obstruction lights. The last two types of lights are special categories which are encountered only on bridges over navigable waterways or on bridges having high towers. There will, of course, be many bridges with no lighting at all.

3-17. Dolphins and fenders

Dolphins and fenders around bridges protect the structure against collision by maneuvering vessels. The fender system absorbs the energy of physical contact with the vessel. The various types of dolphins and fenders are as follows:

a. Dolphins.

(1) *Timber pile clusters.* This type of dolphin is widely used and consists of a cluster of timber piles driven into the harbor bottom with the tops pulled together and wrapped tightly with wire rope (figure 3-18).

(2) *Steel tubes.* Steel tube dolphins are composed of one or more steel tubes driven into the harbor bottom and connected at the top with bracing and fendering systems.

(3) Caissons. These are sand-filled, sheet-pile cylinders of large diameter. The top is covered by a concrete slab, and fendering is attached to the outside of the sheets.

b. Fenders.

(1) *Timber bents.* A series of timber piles with timber walers and braces attached to the tops are still used (figure 3-19). Steel piles are sometimes used in lieu of timber.

(2) *Cofferdams.* On large bridges with wide footings, the cofferdam sheets left in place and braced by a concrete wall act as pier protection. A grid or grillage of timber or other resilient material on the outside of the sheets forms a collision mat.

(3) *Steel pile fenders.* Steel piles driven in pairs to form a frame, with a concrete slab tying the piles together, make a good fender. Timber grillages are attached to the outside to absorb collision impact.

(4) *Steel or concrete frames.* Steel or concrete frames are sometimes cantilevered from the pier and faced with a timber or rubber cushioning to reduce collision impact.

(5) *Timber grids.* Timber grids, consisting of posts and walers, are attached directly to the pier (figure 3-18).

(6) *Floating fenders.* Floating frameworks which partly or completely surround the pier are sometimes used as fenders. The main frames are

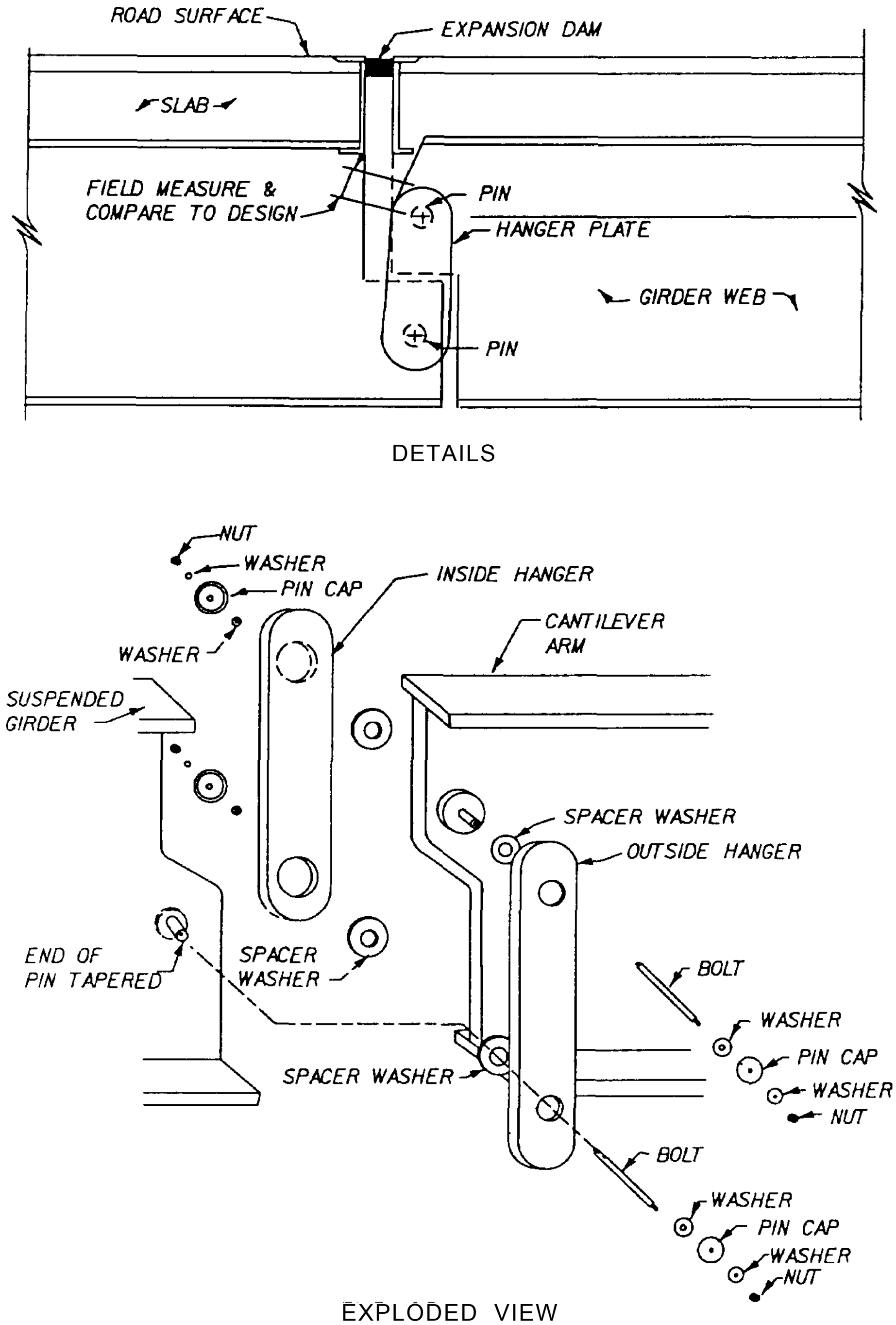


Figure 3-15. Free pin and hanger connection.

usually made of steel or concrete with timber cushioning on the outside face.

(7) *Butyl rubber fenders.* Butyl rubber may be used as a fendering system.

3-18. Welds, bolts, and rivets

a. Welds. Welding is a method of joining two metals together by melting metal at the joints and fusing it with an additional metal from a welding rod. When cool, weld metal and base metal form a continuous and almost homogeneous joint. The two basic types of welds are shown in figure 3-20.

b. Bolts. The A325 high-strength bolt has become the primary field fastener of structural steel. Specifications usually call for a heavy hexagon structural bolt, a heavy semifinished hexagon nut, and one or two washers. Bevel washers may be required.

c. Rivets. Rivets are sometimes used instead of bolts, especially in older structures.

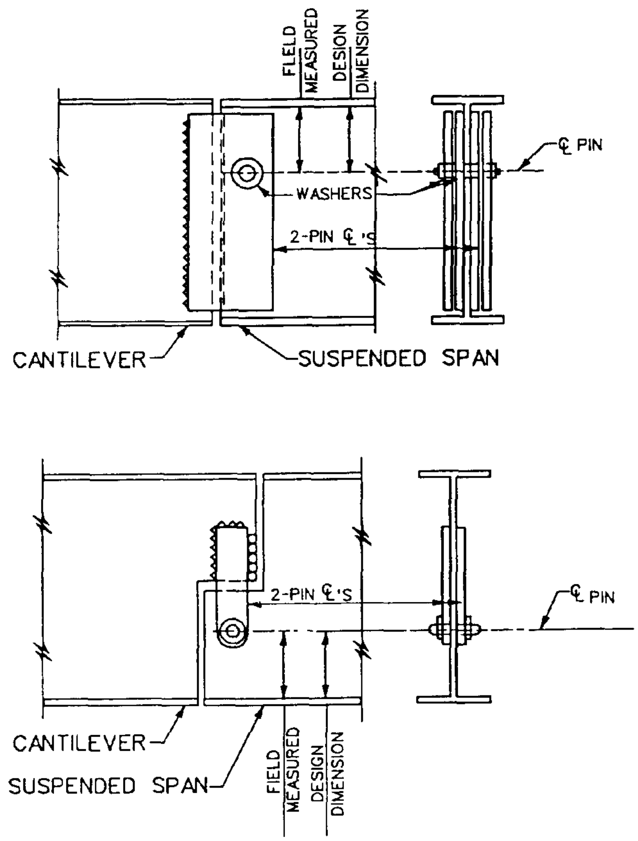


Figure 3-16. Fixed pin and hanger connection.

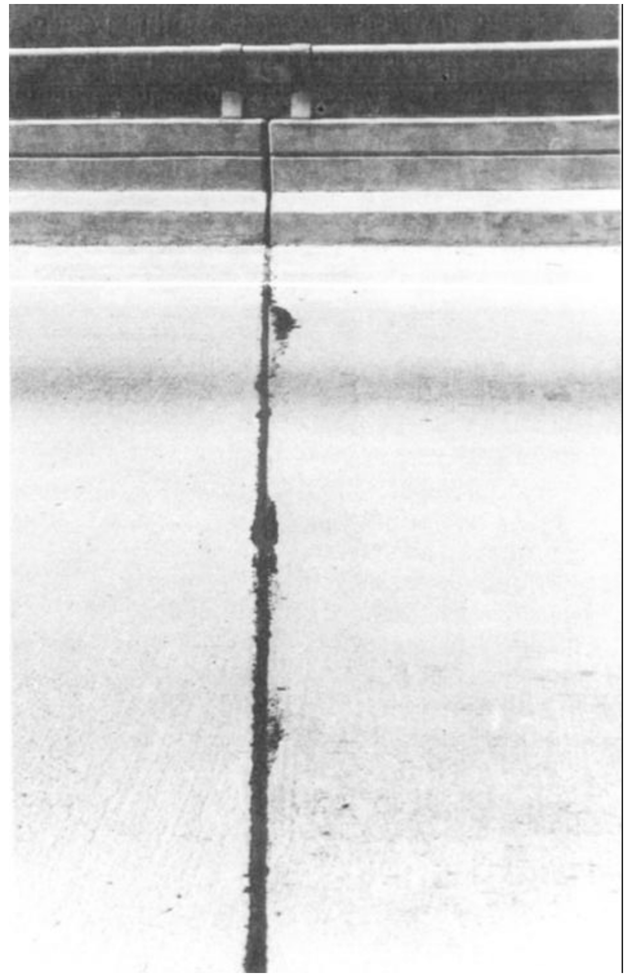


Figure 3-17. Expansion joints. (Sheet 1 of 2)

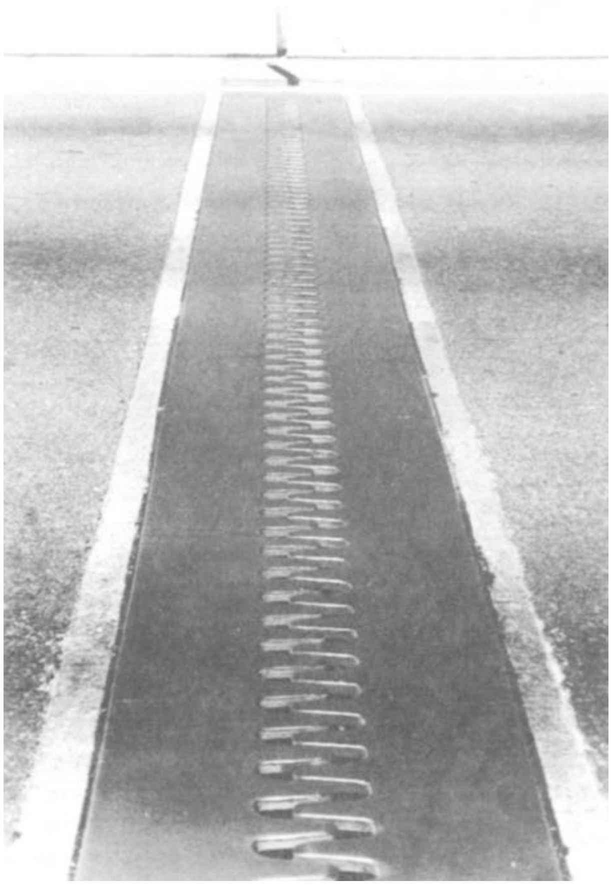


Figure 3-17. Expansion joints. (Sheet 2 of 2)

Figure 3-18. Timber pile cluster dolphins and timber fenders.

Figure 3-19. Timber bent fenders.

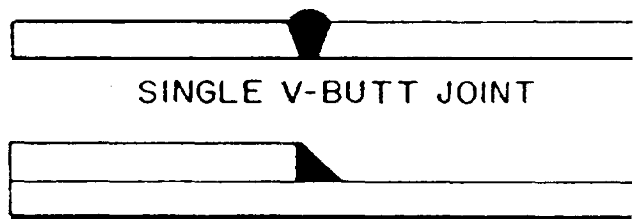


Figure 3-20. Basic weld types.

CHAPTER 4

MECHANICS OF BRIDGES

4-1. General

This chapter provides the inspector with the basics of bridge structures. A more thorough understanding of the behavior of bridges, and the forces imposed on them, will help the inspector to better understand the importance of his job and its associated critical aspects.

4-2. Bridge forces

The solid bodies to be considered are the substructure and the superstructure of the bridges, while the forces exerted on them (represented by arrows in the following diagrams) include various combinations of loads. The principal force is that of gravity acting on the weight of the structure itself (figure 4-1), on the vehicles (figure 4-2), or on other live loads being carried by the structure. Other forces to be considered are those created by earth pressures (figure 4-3); buoyancy or uplift on that portion of a structure which is submerged below water level (figure 4-4); wind loads on the structure, vehicles, or live loads (figure 4-5); longitudinal forces due to changes in speed of the live load or due to friction at the expansion bearings (figure 4-6); temperature change (figure 4-7), earthquake (figure 4-8) stream flow and ice pressure (figure 4-9); and, in the case of masonry structures, shrinkage and elastic rib shortening.

4-3. Stress

The load per unit of area is called unit stress. Unit stress is a very widely used standard for measurement of safe load. Generally, a limiting unit stress is established for a given material. This allowable unit stress multiplied by the cross-sectional area gives the safe load for the member. Since this manual can give only a very elementary introduction to the mechanics of structures, it will be limited to a consideration of the forces due to dead and live loads acting on simple tension or compression members of simple-span structures. For an understanding of other forces and other types of structures, it is suggested that the bridge inspector refer to standard structural analysis textbooks. Loads or forces acting upon members may be classified as axial, transverse, rotational, and torsional. Figures 4-10 and 4-11 illustrate the action of these forces. Both axial and transverse forces are gravity forces and are expressed in pounds, kips (1,000 pounds), tons, or kilograms. When the axial or longitudinal loads exert a pull on the member, the force is said to be tensile; when the axial load pushes or squeezes a member, the force is compressive. In the pure case, axial forces load the cross-sectional area uniformly as shown in figure 4-11. The formula for axial stress is:

$$f = P / A \qquad \text{(eq 4-1)}$$

where

f = stress

P = load

A = cross-sectional area

a. Tension. A simple tension member could be one of the subvertical members of a through truss (figure 4-12). Both dead and live loads cause downward vertical forces which pass from the roadway slab through the stringers and floor beams, each adding its own dead weight force to that already being exerted on it. These combined forces are applied to the subvertical member in question through the floor beam connection to the truss. The tensile force acts on the entire cross section (less rivet or other holes) of the member and produces a certain intensity of stress. If that intensity, or unit stress, is within allowable limits, the member can withstand the applied loads and the member can be considered "safe." If, however, corrosion has reduced the effective area of the member, the intensity of the stress is increased and may exceed the allowable limit. Corrosion may also cause a notch effect which concentrates the stress and further weakens the member.

b. Compression. A simple compression member could be a vertical steel column of a viaduct (figure 4-13). Here the dead and live loads cause downward forces which produce a certain intensity of compressive stress on the entire cross section of the member. In compression members the unit stress not only has to be within allowable limits, as is the case with tension members, but the allowable stress becomes smaller as the slenderness ratio becomes greater. That is, for any given cross section, the longer the column the lower the allowable stress in compression. This is because long compression members will buckle rather than crush.

c. Shear. Transverse forces exert a shearing force or tendency to slide the part of a member to one side of a cross section transversely with respect to the part of the member on the other side of the section. This scissor-like action is illustrated in figure 4-14. Oddly enough, the real shear stress produced by a transverse load is manifested in a

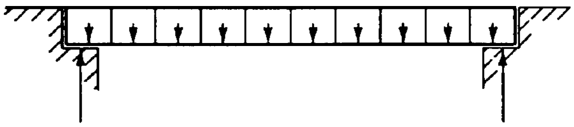


Figure 4-1. Dead load on simple span.

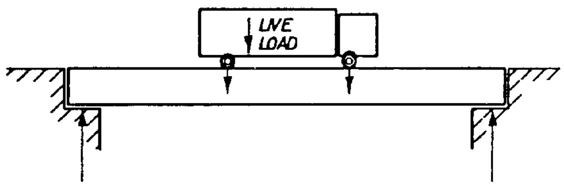


Figure 4-2. Live load on simple span.

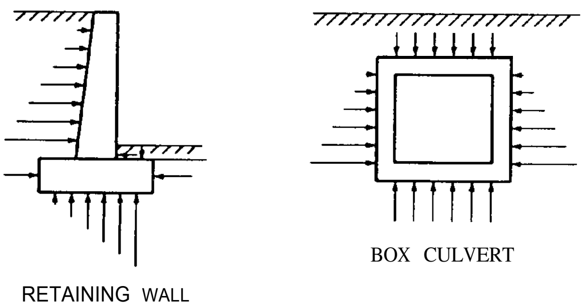


Figure 4-3. Earth pressure.

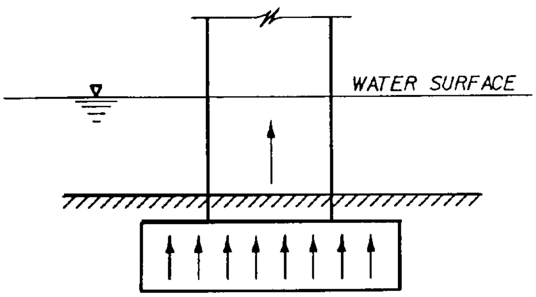


Figure 4-4. Buoyancy on pier.

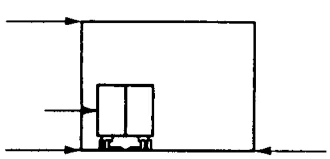


Figure 4-5. Lateral wind load (end view).

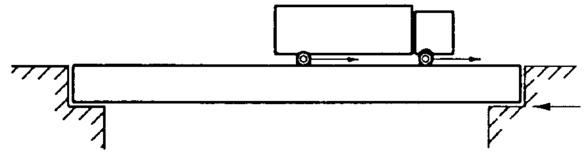


Figure 4-6. Longitudinal force due to friction and live load.

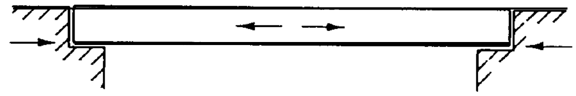


Figure 4-7. Forces due to temperature rise.

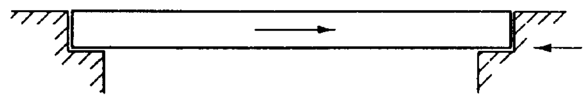


Figure 4-8. Earthquake forces (may be in any direction).

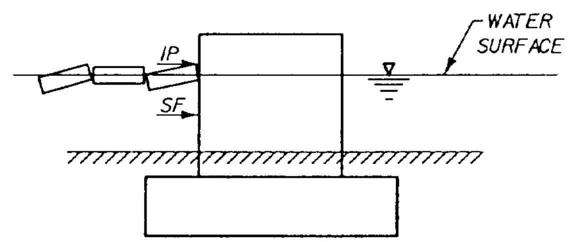


Figure 4-9. Ice pressure and stream flow against pier.

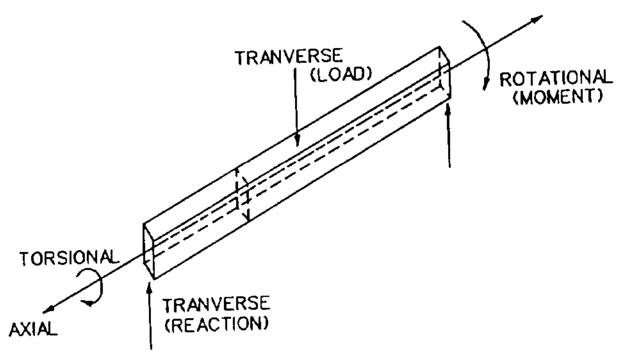


Figure 4-10. Forces on a member.

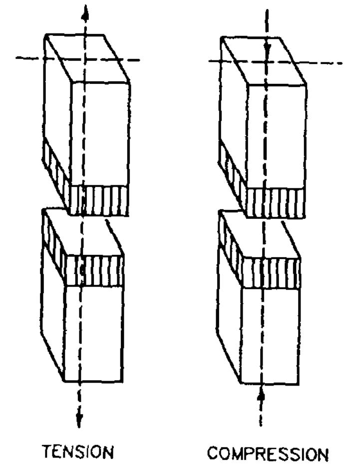


Figure 4-11. Axial forces and stress.

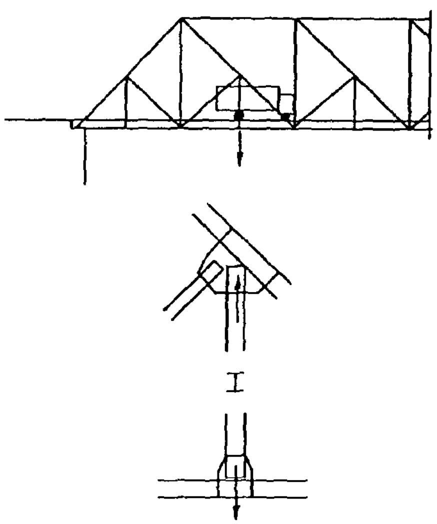


Figure 4-12. Truss vertical in tension.

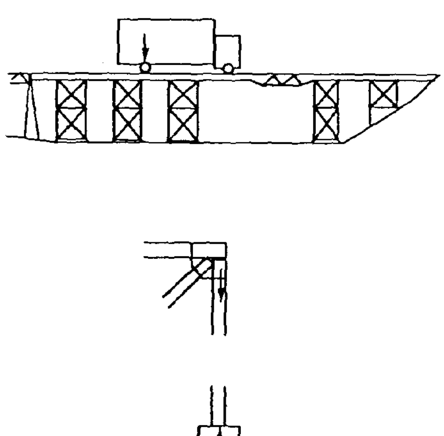


Figure 4-13. Compression.

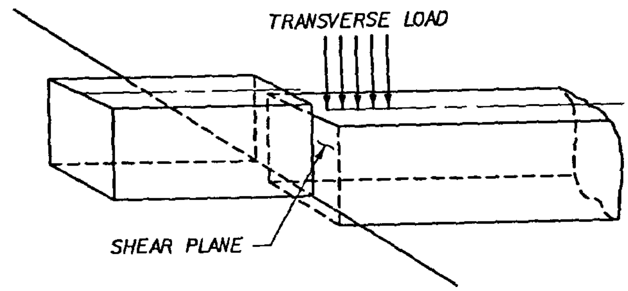


Figure 4-14. Shear forces.

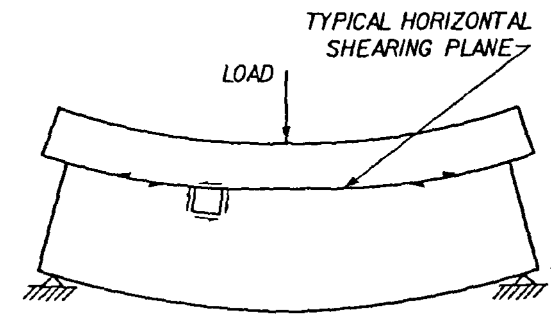


Figure 4-15. Shear. (Sheet 1 of 2)

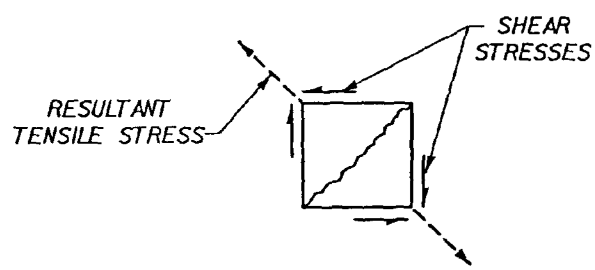


Figure 4-15. Shear. (Sheet 2 of 2)

horizontal shear stress (figure 4-15, sheet 1). However, it is accompanied by a vertical shear stress of equal magnitude as shown in figure 4-15 (sheet 2), which is an enlargement of the little element of figure 4-15 (sheet 1). It can easily be seen that the four shear stresses will combine to form a tensile stress. While this is the most likely source of shear problems, most design criteria consider vertical shear as the criterion of shear strength. The formula for vertical shear stress is:

$f_v = V / A_w$ (eq 4-2)

where

f_v = unit shear stress

V = vertical shear due to external loads

A_w = area of web

d. Rotational force. A rotational force or moment exerts a turning or bending effect on a member in the plane of the member and may be considered as a force acting at the end of a rigid stick. The units of a moment are the product of a force and a distance (or arm). These may be pound-inches, pound-feet, kip-inches, kip-feet, etc. When an external moment is applied to a beam or member, an internal resisting moment is developed. This internal moment is formed by longitudinal compressive and tensile fiber stresses throughout the beam, acting about the neutral axis. This action is illustrated in figure 4-16. Note that the stresses are greatest at the upper and lower beam surfaces and decline linearly to zero at the neutral axis. The maximum flexural (or bending, or fiber) stress are calculated by the following formula:

$f_b = Mc / I$ (eq 4-3)

where

f_b = bending stress

M = moment

c = distance from neutral axis to extreme fiber (or surface) of beam

I = moment of inertia

For stresses at points between the neutral axis and the extreme fiber, use the distance from the neutral axis to the point in question rather than "c." While bending occurs in many structures, it is most common in beam and girder spans. The most common use of a beam is in a simple span. A simple span could be a timber, concrete, or steel beam supported on abutments at each end. The dead and live loads cause downward forces which, with the reactions form external moments, result in the bending of the beam between its supports. The bending produces compressive stresses in the upper, or concave, portion of the beam and tensile stresses in the lower or convex portion of the beam (figure 4-17). A moment producing this type of bending is considered positive. Positive moment is typical of vertical loads acting on simple beams.

e. Negative movement. A continuous (over intermediate supports) beam is shown in figure 2-1 (part b). It is apparent that the same type of loading will produce a positive moment acting on the middle of the span. However, over the support, the upper part of the beam will elongate while the lower part will shorten. This is called negative moment and is present in continuous structures. A negative moment can also be produced in a simple beam (figure 2-1, part a> by an uplift force.

f. Vertical loads. In addition to these horizontal fiber stresses, the vertical loads on the structure are carried to the reactions at the span ends by means of shearing stress in the web of the beam. The beam must, of course, be sized so that all the stresses which it is to withstand will be within allowable limits. It is also important that the beam be rigid enough to keep its deflection within proper limits even when the stresses do not approach limiting values.

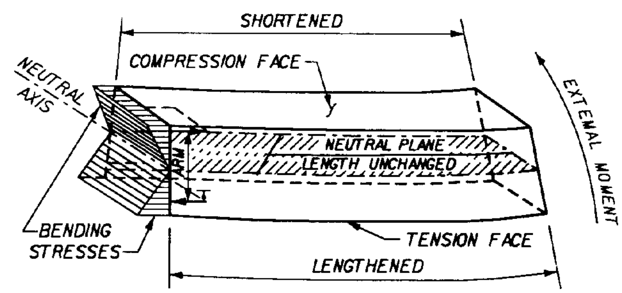


Figure 4-16. Bending stress in a beam.

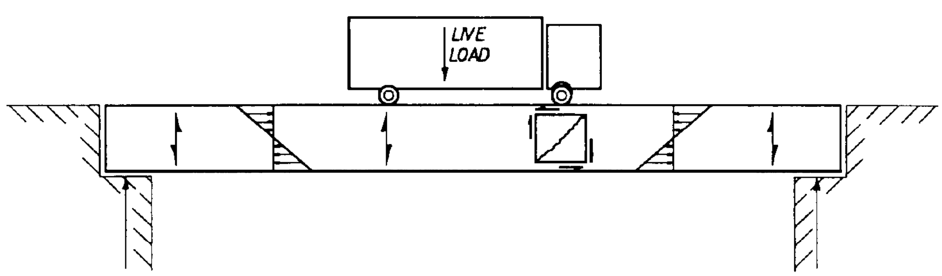


Figure 4-17. Simple beam bending moment and shear.

APPENDIX A

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APPENDIX B

SUGGESTED ITEMS FOR ARMY ANNUAL AND AIR FORCE BIANNUAL BRIDGE INSPECTIONS

BRIDGE INSPECTION ITEMS

Include the following items:

1. Installation.
2. Bridge number.
3. Location.
4. Date inspected.
5. Existing bridge classification (if applicable).

For the following components, address each appropriate inspection item and make notes of any observed deficiencies and recommendations:

A. Timber Abutments

1. Signs of settlement.
2. Rusting of steel rods.
3. Decay of end dam, wingpost, post, and/or cap.
4. Deterioration of block (bearing and anchor).
5. Decay of sill and footing.
6. Loose timbers.
7. Decay of breakage of piles (wing or bearing).

B. Steel Pile Abutments

1. Settlement.
2. Rusting of end dam, pile and/or cap.
3. Section loss of steel members.
4. Missing, loose, or rusting bolts.

C. Concrete Abutments, Wingwalls, and Retaining Walls

1. Settlement.
2. Proper function of weep holes.
3. Cracking or spalling of bearing seats.
4. Deterioration of cracking of concrete.
5. Exposed reinforcing steel.

D. Timber Piers and Bents

1. Settlement.
2. Decay of caps, bracing, scabbing, or corbels.
3. Missing posts or piles.
4. Decay of posts or piles.
5. Debris around or against piers.
6. Section loss of sills or footings.
7. Erosion around piers.
8. Rusting of wire-rope cross bracing.
9. Loose or missing bolts.
10. Splitting or crushing of the timber when:
    a. The cap bears directly upon the cap, or
    b. Beam bears directly upon the cap.
11. Excessive deflection or movement of members.

E. Steel Piers and Bents

1. Settlement or misalignment.
2. Rusting of steel members or bearings.

3. Debris.
4. Rotation of steel cap due to eccentric connection.
5. Braces with broken connections or loose rivets or bolts.
6. Member damage from collision.
7. Need for painting.
8. Signs of excessive deflection or movement of members.

F. Concrete Piers and Bents

1. Settlement.
2. Deterioration or spalling of concrete.
3. Cracking of pier columns and/or pier caps.
4. Cracking or spalling of bearing seats.
5. Exposed reinforcing steel.
6. Debris around piers or bents.
7. Section loss of footings.
8. Erosion around piers.
9. Collision damage.

G. Concrete (girders, beams, frames, etc.)

1. Spalling (give special attention to points of bearing).
2. Diagonal cracking, especially near supports.
3. Vertical cracks or disintegration of concrete, especially in the area of the tension steel.
4. Excessive vibration or deflection during vehicle passage.
5. Corrosion or exposure of reinforcing steel.
6. Corroded, misaligned, frozen, or loose metal bearings.
7. Tearing, splitting, bulging of elastomeric bearing pads.

H. Timber (trusses, beams, stringers, etc.)

1. Broken, deteriorated, or loose shear connectors.
2. Failure, bowing, or joint separation of individual members of trusses.
3. Loose, broken, or worn planks on the timber deck.
4. Improper functioning of members.
5. Rotting or deterioration of members.

I. Steel (girders, stringers, floor beams, diaphragms, cross frames, portals, sway frames, lateral bracing, truss members, bearing and anchorage, eyebars, cables, and fittings)

1. Corrosion and deterioration along:
   a. Web flange.
   b. Around bolts and rivets heads.
   c. Under deck joints.
   d. Any other points which may be exposed to roadway drainage.
   e. Eyebars, cables, and fittings.
2. Signs of misalignment or distortion due to overstress, collision, or fire.
3. Wrinkles, waves, cracks, or damage in the web and flange of steel beam, particularly near points of bearing.
4. Unusual vibration or excessive deflection occurring during the passage of heavy loads.
5. Frozen or loose bearings.
6. Splitting, tearing, or bulging in elastomeric bearing pads.

J. Concrete Appurtenances

1. Cracking, scaling, and spalling on the:
   a. Deck surface.
   b. Deck underside.
   c. Wearing surface (map cracking, potholes, etc.).

NOTE: If deterioration is suspected, remove a small section of the wearing surface in order to check the condition of the concrete deck.

2. Exposed and/or rusting reinforcing steel.
3. Loose or deteriorated joint sealant.

4. Adequacy of sidewalk drainage.
5. Effect of additional wearing surfaces on adequacy of curb height.

K. Timber Appurtenances

1. Loose, broken, or worn planks.
2. Evidence of decay, particularly at the contact point with the stringer where moisture accumulates.
3. Excessive deflection or loose members with the passing of traffic.
4. Effect of additional wearing surfaces on adequacy of curb height.

L. Steel Appurtenances (including but not limited to decks, gratings, curbs, and sidewalks)

1. Corroded or cracked welds.
2. Slipperiness when deck or steel sidewalk is wet.
3. Loose fasteners or loose connections.
4. Horizontal and vertical misalignment and/or collision damage.

M. Masonry Bridges

1. Settlement.
2. Proper function of weep holes.
3. Collision damage.
4. Spalling or splitting of rocks.
5. Loose or cracked mortar.
6. Plant growth, such as lichens and ivy, attaching to stone surfaces.
7. Marine borers attacking the rock and mortar.

N. Miscellaneous

1. Existence and appropriateness of bridge classification signs.
2. Condition of approachments.
3. Leaks, breaks, cracks, or deterioration of pipes, ducts, or other utilities.
4. Damaged or loose utility supports.
5. Wear or deterioration in the shielding and insulation of power cables.

APPENDIX C

SUGGESTED ITEMS FOR ARMY TRIENNIAL AND EVERY THIRD AIR FORCE BIANNUAL BRIDGE INSPECTIONS

BRIDGE INSPECTION ITEMS

Include the following items:

A. General Information to Include

1. Bridge name.
2. Location.
3. Date of inspection.
4. Design load (if known).
5. Military load classification (if known).
6. Date built.
7. Traffic lanes.
8. Transverse section (describe or sketch).
9. Structure length.
10. No. of spans.
11. Plans available.
12. Inspection records.
   a. Year inspected.
   b. Inspector.
   c. Qualification.
13. Bridge description.
   a. Floor system.
   b. Beams.
   c. Girders.
   d. Stringers.
   e. Trusses.
   f. Suspension.
   g. Piers.
   h. Abutment A.
   i. Abutment B.
   j. Foundation.
   k. Piers or bents.
      (1) Caps.
      (2) Posts or columns.
      (3) Footings.
      (4) Piles.
      (5) Other.
   l. Deck:
      (1) Wearing surface.
      (2) Curb.
      (3) Railings.
      (4) Sidewalk.
      (5) Other.

B. Bridge Components Rating Information

The following items may be rated using the suggested ratings from part C of this appendix. Descriptive remarks may also be included.

1. Traffic safety features.
   a. Bridge railing.

b. Transitions.
c. Approach guardrail.
d. Approach guardrail terminal.

2. Deck.
a. Wearing surface.
b. Deck structural condition.
c. Curbs.
d. Median.
e. Sidewalk.
f. Parapet.
g. Railings.
h. Drains.
i. Lighting.
j. Utilities.
k. Expansion joints.

3. Load bearing components.
a. Bearing devices.
b. Stringers.
c. Girders or beams.
(1) General.
(2) Cross frames.
(3) Bracing.
d. Floor beams.
e. Trusses.
(1) General.
(2) Portals.
(3) Bracing.
f. Paint.

4. Abutments.
a. Wings.
b. Backwall.
c. Bearing seats.
d. Breast wall.
e. Weep holes.
f. Footing.
g. Piles.
h. Bracing.
i. Erosion or scour.
j. Settlement.

5. Piers/bents or pile bents.
a. Caps.
b. Bearing seats.
c. Column, stem, or wall.
d. Footing.
e. Piles.
f. Bracing.
g. Erosion or scour.
h. Settlement.

6. Channel and channel protection.
a. Channel scour.
b. Embankment erosion.
c. Drift.
d. Vegetation.
e. Fender system.
f. Spur dikes and jetties.

g. Rip rap.
h. Adequacy of opening.

7. Approach.
   a. Alignment.
   b. Approach.
   c. Relief joints.
   d. Approach.
      (1) Guardrail.
      (2) Pavement.
      (3) Embankment.

C. Suggested Component Ratings

1. Traffic Safety Features.

Code	*Description*
0	Inspected feature DOES NOT currently meet acceptable standards or a safety feature is required and NONE IS PROVIDED.
1	Inspected feature MEETS currently acceptable standards.
N	NOT APPLICABLE

2. Superstructure, Substructure, Channel and Channel Protection, and Approach.

Code	*Description*
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION-no problems noted.
7	GOOD CONDITION-some minor problems.
6	SATISFACTORY CONDITION-structural elements show some minor deterioration.
5	FAIR CONDITION-all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION-advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION-loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION-advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION-major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION-out of service-beyond corrective action.

3. Supplemental for Channel and Channel Protection (Use in conjunction with part 2 above).

Code	*Description*
N	NOT APPLICABLE bridge is not over a waterway.
9	There are no noticeable or noteworthy deficiencies which affect the condition of the channel.
8	Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition.
7	Bank protection is in need of minor repairs. River control devices and embankment protection have little minor damage. Banks and/or channel have minor amounts of drift.
6	Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. There is minor stream bed movement evident. Debris is restricting the waterway slightly.
5	Bank protection is being eroded. River control devices or embankment have major damage. Trees and brush restrict the channel.

Code	*Description*
4	Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the waterways.
3	Bank protection has failed. River control devices have been destroyed. Stream bed aggradation, degradation, or lateral movement has changed the waterway to now threaten the bridge or approach roadway.
2	The waterway has changed to the extent the bridge is near a state of collapse.
1	Bridge is closed because of channel failure. Corrective action may put it back in light service.
0	Bridge is closed because of channel failure. Replacement is necessary.

4. Supplemental for Approach Roadway Alignment (Use in conjunction with part 2 above):

Code	*Description*
8	Speed reduction is NOT required.
6	A VERY MINOR speed reduction is required.
3	A SUBSTANTIAL speed reduction is required.

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By Order of the Secretaries of the Army and the Air Force:

GORDON R. SULLIVAN
General, United States Army
Chief of Staff

Official:

MILTON H. HAMILTON
Administrative Assistant to the
Secretary of the Army

OFFICIAL

JAMES E. McCARTHY
Major General, United States Air Force
The Civil Engineer

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Bridge Inspection, Maintenance and Repair Part I
Updated on: 7/27/2012

1. Which of the following is a type of inspection?

    a) Operator inspection
    b) Preventative maintenance inspection
    c) Control inspection
    d) all of the above

2. Routine maintenance includes all of the following, **EXCEPT** _________.

    a) adjusting bearings
    b) completing repainting
    c) repairing potholes
    d) readjustment of forces (such as in cables)

3. Major maintenance approaches rehabilitation in that in includes _________.

    a) replacement of bearings
    b) cable adjustments
    c) fatigue crack repair
    d) all of the above

4. The depth and frequency to which bridges are inspected will depend on the following factories, **EXCEPT** _________.

    a) age
    b) traffic characteristics
    c) state of maintenance
    d) iconic value

5. More frequent inspections shall be made if significant change has occurred as a result of _________.

    a) floods
    b) earthquakes
    c) excessive loadings
    d) all of the above

6. Which of the following is **NOT** one of the typical roadway classifications?

    a) Interstate
    b) Freeway
    c) Principal Arterial
    d) Side road

7. Which of the following is not one of the basic types of structural framing systems?

   a) Simple spans
   b) Continuous spans
   c) Cantilever and suspended spans
   d) Invert span

8. Super structure types include which of the following?

   a) Slab
   b) Truss
   c) Girder
   d) all of the above

9. The basic types of structural materials include all of the following, **EXCEPT** __________.

   a) aluminum
   b) steel
   c) timber
   d) perlite

10. Box culverts can be as large as __________.

    a) 10' x 10'
    b) 20' x 20'
    c) 40' x 40'
    d) 60' x 60'

11. On a two span continuous girder which of the following is true?

    a) The top of the beam over the middle support is in tension
    b) The top of the beam over the middle support is in compression
    c) The bottom of the beam at the right and left spans are in compression
    d) none of the above

12. Which of the following is **NOT** a typical substructure element?

    a) Abutments
    b) Piers
    c) Bents
    d) Support cables

13. Which of the following is a typical substructure element?

    a) Decks
    b) Floor systems
    c) Main support members
    d) all of the above

14. Main support members include all of the following, **EXCEPT** __________.

a) Rolled beams
b) Plate girders (built up)
c) Concrete beams
d) Siplast systems

15. Built up plate girders are usually used when __________.

a) a rolled beam is inadequate
b) the designer wants to save on labor
c) a truss is not warranted for the force in action
d) both a) and c)

16. Which of the following is **NOT** an element of built up members?

a) Flange angles
b) Cover plats
c) Bearing stiffeners
d) Clip angles

17. Trusses include the following members, **EXCEPT** __________.

a) chords
b) vertical web members
c) diagonal web members
d) compression cables

18. __________ transmit loads from the substructure to the super structure.

a) Bearings
b) Expansion joints
c) Lateral braces
d) Piers

19. __________ bearings are free to move in the direction of the bridge span.

a) Simple expansion
b) Roller expansion
c) Fixed
d) both a) and b)

20. Force / Cross Sectional Area = __________.

a) stress
b) moment
c) tensile capacity
d) Euler stress