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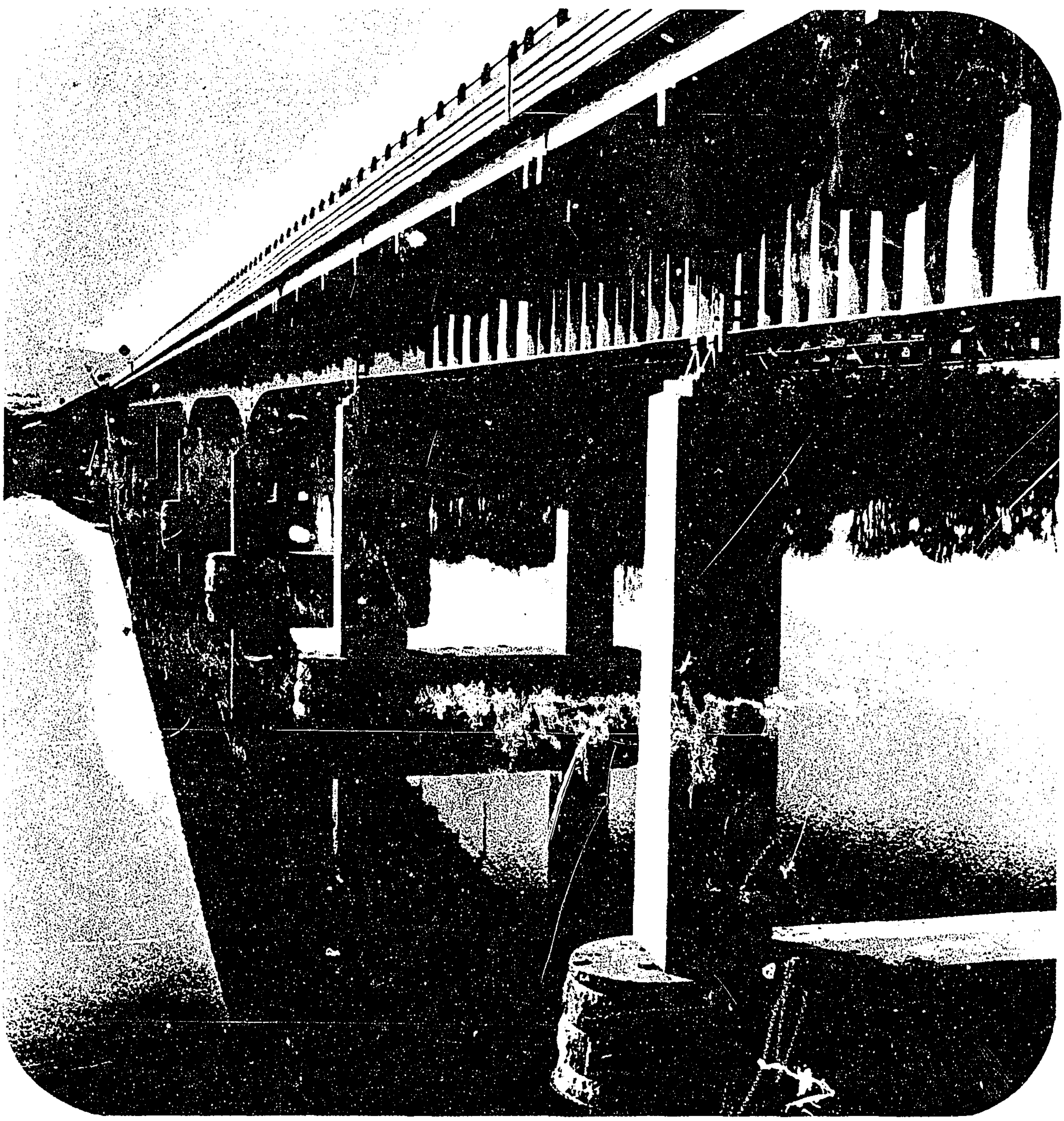
ABSTRACT

A guide for the instruction of bridge inspectors is provided in this manual as well as instructions for conducting and reporting on a bridge inspection. The chapters outline the qualifications necessary to become a bridge inspector. The subject areas covered are: The Bridge Inspector, Bridge Structures, Bridge Inspection Reporting System, Inspection Procedures, Bridge Component Inspection Guidance, and Reports and Recommendations. The duties of an inspector and the requirements for his training are laid out in chapters one through four. Chapter five covers the construction and design aspects of bridges together with the explanation of mechanical principles. The nature and theory of bridge construction occupies approximately two thirds of the manual. The rest of the manual covers the inspection field book, inspection equipment, foundation movements and effects on bridges, the nature of underwater inspections, and structural bridge deficiencies. There are extensive diagrams, photographs, a glossary of bridge engineering and inspection terms, and a 62-item bibliography. (KP)

# BRIDGE INSPECTOR'S TRAINING MANUAL 70



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*U. S. DEPARTMENT OF TRANSPORTATION*
*FEDERAL HIGHWAY ADMINISTRATION*
*BUREAU OF PUBLIC ROADS*
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The Bridge Division of the Office of Engineering and Operations of the Bureau of Public Roads in cooperation with the Chairman of the Subcommittee on Bridge Maintenance of the Operating Committee on Maintenance and Equipment, American Association of State Highway Officials (A.A.S.H.O.), along with other affiliated State highway engineers, has prepared this *Bridge Inspector's Training Manual.*

The help of all whose efforts and encouragement were of aid in completing this venture is acknowledged. Thanks are due to many individuals and state organizations for a large number of illustrations used in the text, a practical indication of the interest all concerned have exhibited in completing this project.

To Mr. Vernon W. Smith, Assistant Highway Maintenance Engineer, Georgia State Highway Department; Mr. Samuel M. Cardone, Engineer of Structure Maintenance, Michigan Department of Highways; and Dr. Robert A. Norton, Engineer of Bridges and Structures, Connecticut Department of Transportation, Bureau of Highways, goes a special note of thanks. Mr. Smith contributed the material on the inspection reporting system contained in Chapter III. The text in Chapter VI covering reports and recommendations, is essentially the work of Mr. Cardone. Chapter II, Bridge Structures, represents the diligent efforts of Dr. Norton.

Finally, acknowledgement is in order for the assistance provided by the Silver Spring, Maryland, Operation of Link Division of Singer Company in the assemblage and shaping of the manual into its final form.

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# INTRODUCTION

The bridge structures of today reflect the technological advances in design, construction, and safeguards that have evolved over the years. Nevertheless, these advances have not precluded unfortunate and, in some instances, tragic occurrences. The collapse of the Silver Bridge, in 1967, aroused increased interest in the inspection and maintenance of bridges and prompted the United States Congress to add a section to the Federal-Aid Highway Act of 1968 requiring the Secretary of Transportation to establish a national bridge inspection standard and to develop a program to train bridge inspectors.

The purpose of this manual is to provide guidelines for the training of bridge inspectors. It is not intended to provide a definitive treatment of bridge inspection. It is neither an inspection manual nor a textbook for bridge inspections. This manual is, however, a guide both for instruction and for the conduct of bridge inspections.

Chapter I of this manual outlines, in general terms, the primary duties of the bridge inspector, the essential requirements for the training of bridge inspectors, and the prerequisite qualifications for individuals selected for such training. Chapter II provides a simplified classification of bridge types and a rudimentary explanation of simple mechanics. The planning of a bridge inspection operation and the use of an inspection field book are explained in Chapter III. Chapter IV describes the methodology and the procedural sequence to be followed in conducting a bridge inspection. Chapter V covers the characteristics and weaknesses of the major construction materials, and explains the nature and causes of foundation movements and their effects upon bridges. A description of typical structural deficiencies composes the bulk of this chapter. A brief discussion of the methods of reporting inspection results and making recommendations is contained in Chapter VI. The manual also contains a glossary of commonly used bridge engineering and inspection terms and a short bibliography.

The success of any training program is highly dependent on the qualifications and motivation of the individuals concerned. While some states currently use graduate engineers to conduct bridge inspections, this will not always be possible. A bright, industrious, high school graduate or, perhaps, a graduate of a junior or two-year college who is motivated, interested, and willing to work can compensate for the lack of formal education. A realization of the importance of this work and the dedication and determination to do a good job are essential prerequisites. Good health and physical agility are two highly desirable qualifications. While not necessary, some experience in structural erection or construction is also desirable. Aside from physical fitness, the inspector trainee must be literate, have an understanding of drafting, be capable of reading bridge construction plans, and be able to use simple inspection equipment.

The critical ingredients of the bridge inspector's tasks are the care he exercises in the inspection of a bridge, the thoroughness with which he covers every aspect of the structure, the clarity and comprehensiveness with which he reports the conditions he finds, the soundness of his recommendations, and the enthusiasm with which he approaches each day's work.

The task of inspecting a bridge is, in most instances, a complex technical assignment requiring specialized skills and experience. Moreover, each bridge inspector shares a tremendous dual public responsibility. He is relied upon to guarantee public safety and to protect public investment with respect to bridges. The inspector discharges this responsibility through inspection and the reporting of those bridge conditions and situations which presently impair, or may potentially impair, either public safety or investment. Each bridge inspector must, therefore, be properly and thoroughly trained to recognize, record, evaluate, and report bridge conditions.

# CHAPTER I

# THE INSPECTOR

### *Section 1. QUALIFICATIONS, DUTIES, AND EQUIPMENT*

#### 1–1.1 General.

It is the responsibility of the bridge engineer of today to utilize his technical skill to preserve and maintain all existing bridges so that they may continue to serve us until they can no longer endure the burdens of modern day loadings. All bridges, regardless of type, have certain basic common components. This publication will familiarize the potential inspector with the various types of bridges and their component parts. It will assist in the training of selected individuals in the inspection, identification, and reporting of deterioration, malfunctioning, and potential hazards of the nation's bridges. In this chapter the qualifications and duties of the inspector, and the tools and equipment he needs will be outlined.

#### 1–1.2 Qualifications of the Inspector.

a. *Training and Education.* Graduation from a standard or vocational high school is a minimum requirement. Completion of two years of engineering school or the completion of a two-year technical course in an institute of applied science, is desirable.

b. *Experience.* While not mandatory, five years of experience in one or more of the following related fields is desirable:

(1) Structural maintenance
(2) Structural inspection
(3) High steel construction
(4) Surveying

c. *Physical Ability.* Inspecting, sketching, and photographing bridge components while in difficult positions or at great heights will sometimes be necessary. The applicant should be able to climb structural steel without difficulty. The inspector will be occasionally required to work during periods of adverse weather.

d. *Skills.* The bridge inspector should be able to letter legibly and read at the level of the average high school graduate. He should possess average mechanical aptitude and a working knowledge of the use of measuring devices such as rulers, tapes, feeler gauges, protractors, calipers and thermometers. He should have the ability to read bridge plans, visualize details, operate a camera, and draw technical sketches of bridge components. He should have an awareness of potential hazards and exhibit a serious attitude toward the safety precautions to be taken while climbing and inspecting bridges.

e. *Attitude.* The inspector must approach each task critically with the expectation of detecting serious defects or deficiencies.

f. *Motivation.* The inspector must want to do a good job. All of the above qualities are of little value without the determination to perform well.

#### 1–1.3 Typical Duties of the Inspector.

a. Assists in the planning and preparation of bridge inspections

b. Inspects bridge components for deterioration

c. Sketches bridge components

d. Photographs various problem areas

e. Takes technical measurements

f. Records rotation and translation data for appropriate components

g. Notifies supervisor of hazardous conditions

h. Makes basic computations

i. Maintains records of inspection results

### 1–1.4 Tools and Equipment.

a. *Special Equipment.* The inspecting agency has the responsibility for providing access to the various locations on the structure that cannot be observed and/or inspected without the use of special equipment. The following is a list of some of the special equipment that may be required:

(1) Ladders

(2) Scaffolds (Travelers or cabling)

(3) "Snooper" or "Cherry Picker" (Truck-mounted bucket on a hydraulically operated boom (or on a platform truck))

(4) Burning, drilling, and grinding equipment

(5) Sand or shot blasting equipment

(6) Boat or barge

(7) Diving equipment (Scuba or hard hat)

(8) Sounding equipment (Lead lines or electronic depth finders)

(9) Transit level, or other surveying equipment

(10) Television camera for underwater use on closed circuit television with video tape recorder

(11) Magnetic locator for rebars

(12) Helicopters

(13) Air jet equipment

(14) Air breathing apparatus

(15) Mechanical ventilation equipment (Blowers and air pipes)

(16) Pre-entry air test equipment (Devices to test oxygen content and to detect noxious gasses)

(17) Ultrasonic equipment

(18) Radiographic equipment

(19) Magnetic particle equipment

(20) Dye penetrants

NOTE: Ultrasonic, radiographic, magnetic particle; and dye penetrant and other non-destructive methods are beyond the scope of the average inspection. In this manual they are referred to as the "more sophisticated methods" of testing.

b. *Standard Tools.* The inspector should be provided with and able to use the following tools:

(1) Pocket tapes and folding rules

(2) Chipping hammer (6 ounce)

(3) Scraper (2 inch)

(4) Inspection mirror on a swivel head and extension arm

(5) Center punch

(6) Scribe

(7) Calipers

(8) "C"-clamps

(9) Plumb bob

(10) Straight edge

(11) 100 foot tape

(12) Feeler gauges

(13) Sounding line

(14) Thermometers—Air and Contact

(15) Penetrating Oil

(16) Binoculars

(17) Camera (Color or black and white film)

(18) Safety belts

(19) Paint film gauges

(20) Field books, inspection forms, clip boards, chalk, keel or markers

(21) Screw driver (Large)

(22) Heavy duty pliers

(23) Protractor

(24) Flashlight

(25) Pocket knife

(26) Increment borer

(27) Corrosion meter

(28) Wire brush

(29) Ice pick

c. *Clothing.* The inspector should dress in appropriate seasonal work clothes. Overdressing in bulky, cumbersome clothing is not recommended as it hinders freedom of motion and will often prevent entrance into confined areas. Three important articles of wearing apparel are boots, leather gloves and the safety hat. Boots should be of the bridge shoe type with either cork or rubber soles. Overshoes, such as rubber arctics, must be completely buckled if worn, especially while walking on the structure.

## Section 2. SAFETY

### 1–2.1 General.

The safety of the bridge inspector is of the utmost importance. While the work may be hazardous, the accident probability may be limited by proceeding cautiously. The following rules should be observed:

a. Always be careful, use good judgment and prudence in conducting your activities, both for your own safety and that of others.

b. If you wear glasses, wear them when climbing. The wearing of bifocals is an exception to this rule. Only regular single lens glasses should be worn while climbing. Where work requiring close-up viewing is to be performed, a separate pair of glasses with lenses ground for this purpose should be worn.

c. Do not drink alcoholic beverages before or during working hours. They impair judgment, reflexes, and coordination.

### 1–2.2 Bridge Site Organization.

a. *General.* The safety of personnel and equipment and the efficiency of bridge inspection operations depend upon proper site organization.

b. *Personnel.* All individuals who are assigned to work aloft must be thoroughly trained in the rigging and use of their equipment, i.e., scaffolds, working platforms, ladders and safety belts. The plans for inspection should give first consideration to safeguarding personnel from possible injuries.

c. *Equipment.* Inspection equipment, highway traffic barricades, and signs should be arranged according to the plan of inspection so as to accomplish as little handling, unnecessary movement, and repositioning as possible. Vehicles not directly involved in the inspection process should be parked so as to prevent congestion and avoid interference in the area of inspection.

d. *Orderliness.* Individuals should develop orderly habits in working and housekeeping on the job.

### 1–2.3 Personal Protection.

It is important to dress properly. Keep clothing and shoes free of grease. Always wear the following required protective equipment:

a. Hard hat with a chin strap.

b. Goggles, face masks, shields, or helmets, when around shot blasting, cutting, welding, etc.

c. Reflective vests or belts when working in traffic.

d. Life preservers or work vests when working over water.

e. Shoes with cork, rubber, or some other non-slip soles.

### 1–2.4 Special Safety Equipment.

a. A life line or belt must be worn when working:

(1) At heights over 20 feet.

(2) Above water.

(3) Above traffic.

b. A life-saving or safety skiff should be provided when working over large rivers or harbors; the skiff should have life preservers and life lines on board.

c. Warning signals, barricades, or flagmen are necessary when the deck is to be inspected, or when scaffolding or platform trucks are used for access to the undersides or bridge seat of a structure. Refer to the Manual on Uniform Traffic Control Devices (MUTCD) for specific traffic control procedures.

### 1–2.5 Climbing of High Steel.

a. It is preferable to work from a traveler, catwalk or platform truck, if possible.

NOTE: On old ladders and catwalks, proceed with extreme caution.

b. *Scaffolding.* When using scaffolding, the following precautions should be observed:

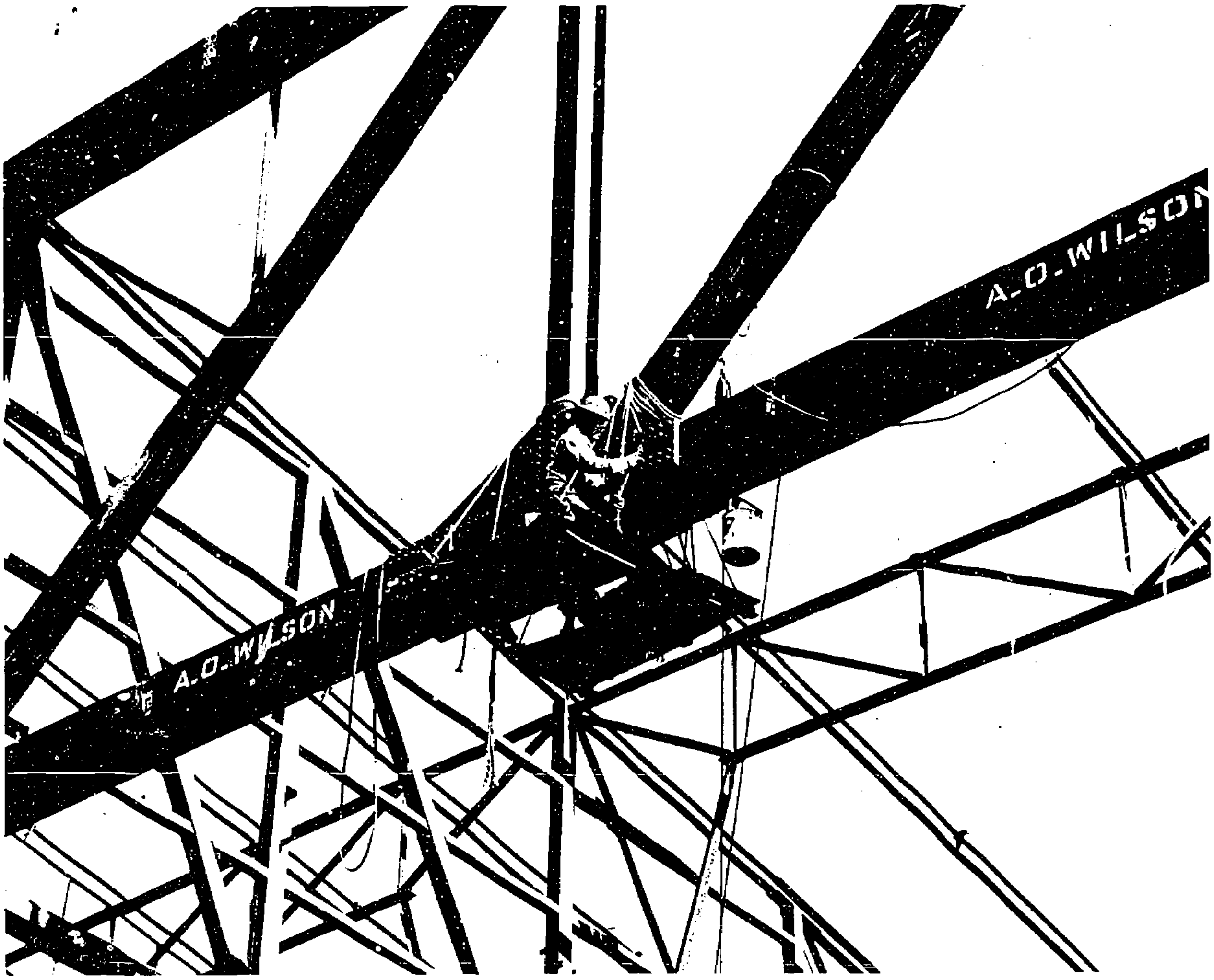
(1) Scaffolding and working platforms should be of ample strength and should be secure against slipping or overturning.

(2) Hanging scaffolds and other light scaffolds supported by ropes should be tested before using by hanging them a foot or so from the ground and loading them with a weight at least four times as great as their working load.

(3) Scaffolds should be inspected at least once each working day.

c. Ladders should be used as working platforms only when it is absolutely necessary to do so. When using ladders the following precautions should be observed:

(1) Make certain that the ladder to be used is soundly constructed. If made of wood, the material should be straight-grained and clear.




Courtesy of Bethlehem Steel Co.

*Figure 1–1. Platform being used on high steel.*

(2) Ladders should be tested to make sure they can carry the intended loads.

(3) Ladders should be blocked at the foot or tied at the top to prevent slipping.

(4) Personnel should be cautioned frequently about the danger of trying to reach too far from a single setting of a ladder.

d. Planks or platforms may be used where necessary (fig. 1–1).

(1) Planks should be large enough for the span.

(2) Never use a single plank. Two planks are a bare minimum; they should be attached by cleats 18″ apart.

e. Keep all catwalks, scaffolds, platforms, etc., free from ice, grease, or other slippery substances or materials.

f. Catwalks, scaffolds, and platforms should have hand rails and toe boards to keep tools or other objects from being kicked off and becoming a hazard to anyone below.

g. Always watch where you are stepping. Do not run or jump.

h. Do not climb if you are tired or upset.

**1–2.6 Confined Spaces.**

a. *General.* In recent years there has been an increasing use of hollow structural members of the tubular or box-section types large enough to permit a man to enter the interior of the member. In bridge work, boxes are used both in large truss bridges and in box girder bridges with rectangular or trapezoidal box-sections. In these types of members, the interior is often closed off at both ends, forming a closed box. This protected interior is high in corrosion resistance even in the bare metal state, a great advantage in the maintenance of the structure. In some closed sections a closable, watertight, and vaportight access manhole is provided to permit inspection of the interior. While the box-section offers both structural and maintenance advantages over other types of sections, there are certain health hazards of which the maintenance inspectors, and others who may be involved with these types of sections, should be aware.

b. *Hazards*. No health hazard exists in confined space if there is proper ventilation. However, a hazardous atmosphere can develop because of a lack of sufficient oxygen or because of a concentration of toxic gases. Oxygen deficiency can be caused by the slow oxidation of organic matter which has become moistened. Toxic gases may seep into the confined space or may be generated by such work processes as painting, burning or welding. The confined space may be of such small volume that air contaminants are produced more quickly than the limited ventilation of the space can overcome. Persons should not be allowed to work in confined spaces containing less than 19% oxygen unless provided with air-breathing apparatus. However, as noted above, a space with sufficient oxygen content can become unfit for human occupancy if the work conducted therein produces toxic fumes or gases. Such space should be occupied by the inspector only after adequate ventilation.

c. *Safety Procedures.*

(1) *Pre-entry air tests.*

(a) Tests for oxygen content should be conducted with an approved oxygen-detecting device. A minimum of two tests should be conducted.

(b) Where the presence of other gases is suspected, test for such gases should be conducted using approved gas-detecting devices. The following gases should be considered:

- Carbon Dioxide
- Carbon Monoxide
- Hydrogen Sulfide
- Methane
- Any combustible gas

(c) If the oxygen content of the air in the space is below 19%, or if noxious gases present are equal, or in excess of 125% of the Threshold Limit Values, established by the American Conference of Governmental Industrial Hygienists, no person should be allowed to enter such space unless mechanical ventilation is applied to the space until the oxygen content and gas content meet the above limits for a minimum period of fifteen (15) minutes.

(2) *Ventilation During Occupancy.*

(a) All confined spaces should be mechanically ventilated continuously during occupancy irrespective of the presence of gas, the depletion of oxygen, or the conduct of contaminant-producing work.

(b) Where contaminant-producing operations are to be conducted, the ventilation scheme should be approved by an Industrial Hygiene Engineer, Safety Engineer, Marine Chemist, or others qualified to approve such operations.

(3) *Air Tests During Occupancy.*

(a) If toxic gas presence or oxygen depletion is detected or suspected, air tests similar to the Pre-entry air tests should be conducted during occupancy at fifteen (15) minute intervals.

(b) Where contaminant-producing operations are conducted, air tests should be conducted to determine the adequacy of the ventilation scheme.

# CHAPTER II

# BRIDGE STRUCTURES

## 2–0.0 Introduction.

This chapter discusses briefly the development of various types of common bridge structures, their components, the materials of which they are constructed, and the manner by which loads are transmitted through the several parts of a bridge structure to its foundations. The bridge maintenance inspector is concerned with all bridges whose structural integrity is essential to the safety of the traveling public and to the uninterrupted use of the highway. Minor culverts are normally the responsibility of the hydraulic or drainage engineer rather than of bridge maintenance personnel. Similarly, specialized and complex structures such as movable bridges or suspension bridges, whose inspection requires specialized personnel and, perhaps, the services of consulting engineers, are also beyond the scope of the average bridge maintenance inspector. The Bibliography will provide the bridge maintenance inspector with additional information about the history, types of bridges, and bridge construction materials. A few of the more important or classic works on the subject of bridges and structures are also listed. Some of the older works may be out of print and may be available only through large technical reference libraries, or the personal libraries of "old-time" engineers.

### *Section 1. HISTORY, MATERIALS, AND TYPES*

## 2–1.1 Log Bridge.

The earliest bridges were, undoubtedly, logs or tree trunks set across a stream or chasm (fig. 2–1). Since timber cannot endure for thousands or even hundreds of years, there are no known remaining examples of this early type of bridge construction. One of the earliest bridges on record was that constructed over the Tiber River at Rome, and defended by Horatius Cocles in the battle against the Etruscans in the late 6th century B.C. It reportedly was a wooden bridge resting on piles. Another notable ancient bridge was constructed by Julius Caesar across the Rhine River in Germany in 55 B.C. (fig. 2–2). This, too, has been described as being a wooden bridge resting on piles.

## 2–1.2 Clapper Bridge.

Another very old type of structure, of which there are still a few remaining examples, is the stone slab or "clapper" bridge, shown in figure 2–3. Although stone is not strong in tension, quality granite, or other hard stone, may be

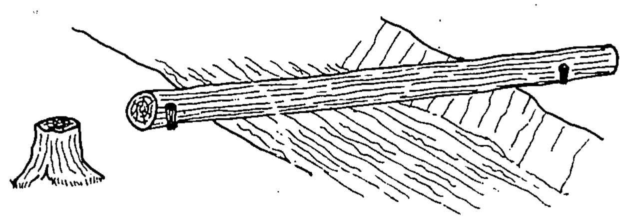


*Figure 2–1. Simple log bridge.*

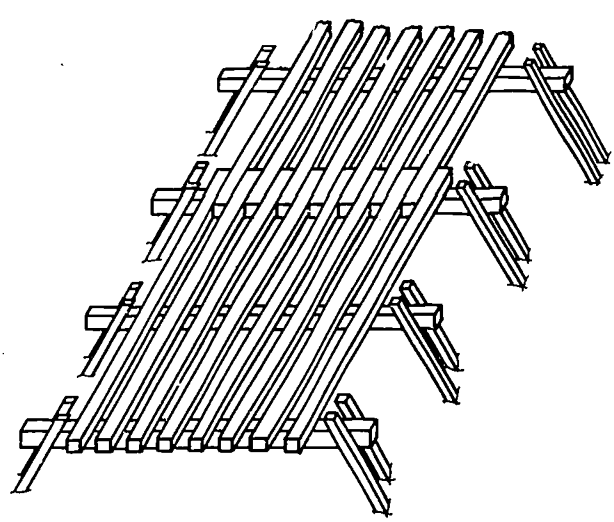


*Figure 2–2. Caesar's bridge.*

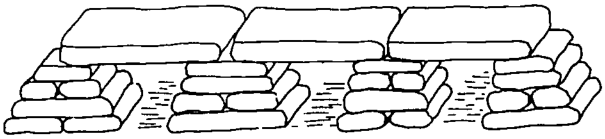


*Figure 2-3. Stone clapper bridge.*

used for simple spans several feet in length. There is an ancient "clapper" bridge of three spans still standing at Dartmoor, England.

### 2-1.3 Stone Masonry Arch Bridge.

a. *False Arch.* The use of stone masonry for the construction of arches dates back to at least 3,000 years before the Christian Era. The Egyptians and other people of the eastern Mediterranean region first developed the corbelled or false arch (fig. 2-4). This type of arch is formed by projecting stones from each side of an opening until they meet at the center. Since the projecting stones carry the applied loads as cantilever arms, rather than by direct compression of the individual stones, as is the case with a true arch ring, they are called false arches. Examples of this type of construction are found in the pyramids of Eygpt dating back to 3000 to 4000 B.C., and at Mycene in Greece, dating back to 1300 B.C. These structures serve as entrances to underground vaults and to fortified palace walls. It is not known whether these earlier arches were used for bridges which could carry traffic.

b. *True Arch.* It is generally agreed that the Etruscans, who lived in north central Italy from the 8th to the 4th century B.C., were familiar with the true stone arch (fig. 2-5) and that the Romans, who developed this form of construction to its peak during the period from 300 B.C. to 200 A.D., learned their skills from the Etruscans. The Romans used stone arches for the construction of both aqueducts and highways (fig. 2-6 and 2-7). Many examples of their work remain today not only in Rome but throughout the once vast Roman empire extending up into Spain and France. With the decline of Roman civilization there followed a period during which the art of bridge building lapsed to such an extent that no new bridges of any importance were constructed for several centuries. It was not until the Middle Ages, when the Crusades began, that bridge building was resumed to any significant extent. Stone masonry arch construction continued to be the principal type of bridge structure from the 12th century until the 18th century. Although the Romans had specialized in the construction of semi-circular arches, the bridges of this period varied from the pointed or Gothic arch ( . 2-8) to the flat or elliptical arch (fig. 2-9).

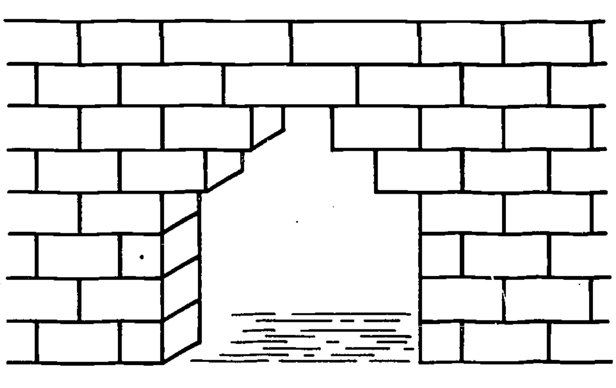


*Figure 2-4. Corbelled or false arch.*

### 2-1.4 Cast Iron and Timber.

During the late 18th century and the first half of the 19th century, new materials and new types of bridges began to appear. The first of these new materials was cast iron, which was

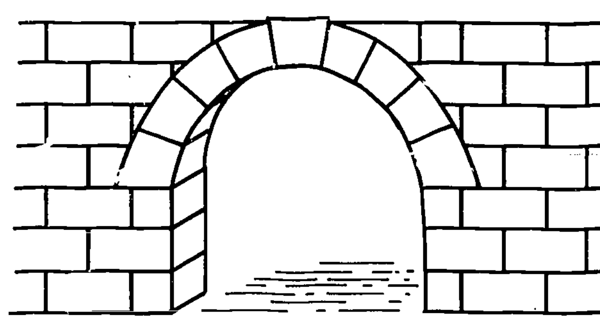


*Figure 2-5. True arch.*

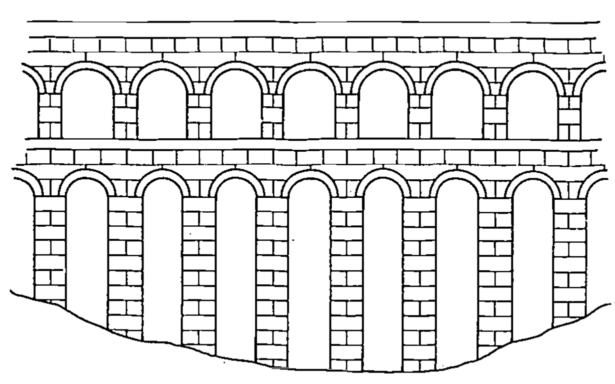


*Figure 2-6. Roman aqueduct.*

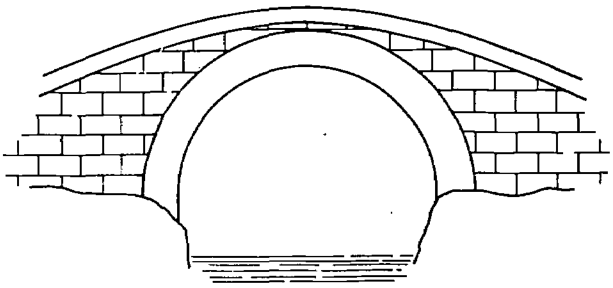


*Figure 2–7. Roman bridge.*

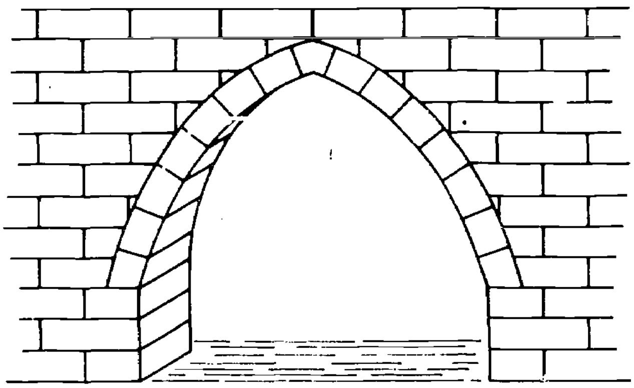


*Figure 2–8. Gothic arch.*

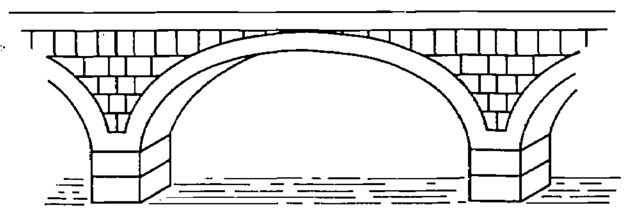


*Figure 2–9. Elliptical arch.*

first used in the construction of an arch bridge across the Severn River in England in 1776. The first suspension bridge in America was built in 1796 at Uniontown, Pennsylvania, using wrought iron chains. Although the use of timber cannot be considered new in bridge building, the development of the timber truss by Ithiel Town, and the introduction of the combined timber and wrought iron truss by Theodore Burr and William Howe in the early 1800's, led to the development of our modern railway and highway systems.

## 2–1.5 Trusses.

The first rational analysis of the stresses in the members of truss spans came in a book published by Squire Whipple in 1847 entitled, "A Work On Bridge Building". Until that time most bridges were constructed by empirical methods, frequently with the use of models tested to destruction. The first long-span truss of the Whipple type was constructed across the Ohio River at Steubenville, Ohio, in 1864. The end posts and all other compression members were of cast iron while all tension members were of wrought iron. A few of these old cast and wrought iron trusses remain in service today.

## 2–1.6 Modern Era.

a. *Steel.* The modern era of bridge building can be said to have begun with the development, in 1855, of the Bessemer process of making steel, followed a few years later by the open-hearth, or Siemens-Martin, process. The first important bridge in America to use the new material was the Eads Bridge over the Mississippi River at St. Louis. This structure, a three-span steel arch bridge more than 1,500 feet in length, was completed in 1874—requiring 6 years for its construction.

b. *Truss Bridge.* Although the Eads Bridge was of steel arch construction, many of the bridges built during the next fifty or more years were steel trusses. So many different types of trusses were developed that it is not possible to describe them all here. However, the sketches in figure 2–10 show many of the more common types used throughout the country. Although for crossings of moderate span, the truss types are rapidly being replaced by beam or girder construction, the many truss bridges still in service are an important class of structures. Most of the older trusses require especially close and knowledgeable inspection since they were constructed before the advent of the heavier live loads such as oil trucks, tandem trailers, and concrete mixers that travel our highways today. Trusses are often located on secondary roads where their proper maintenance may have been overlooked. The failure of one weakened member or connection of a truss bridge can result in the complete collapse of the structure.

c. *Girder Bridge.* Concurrently with the development of truss bridges came the development of beam, or girder, bridges (fig. 2–11). What is probably the first box girder construction was used for the Brittania Bridge over the

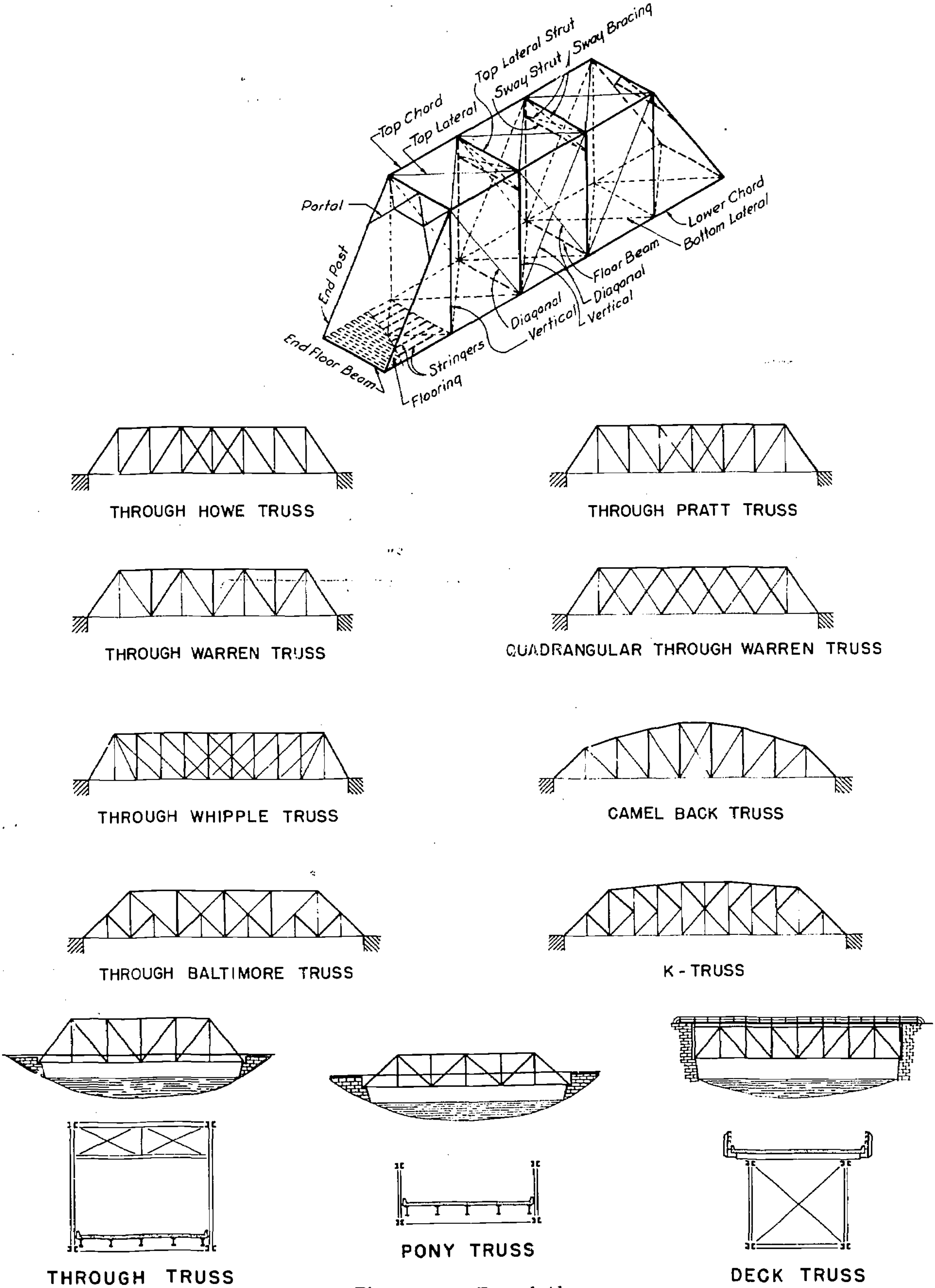
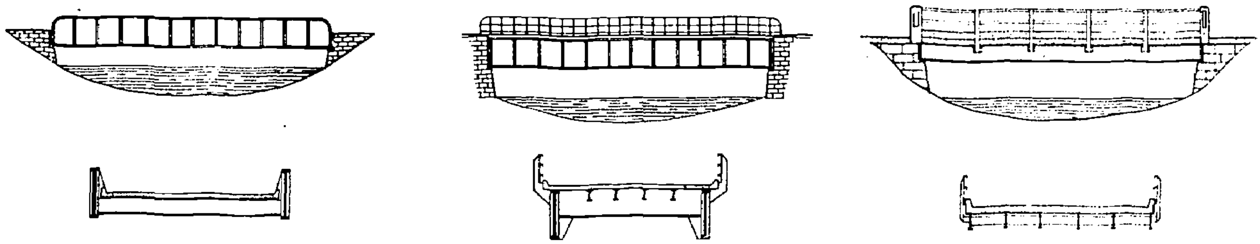



*Figure 2–10. Truss bridges.*



THROUGH GIRDER DECK GIRDER I BEAM

*Figure 2–11. Girder bridges.*

Menai Strait in Wales, built in 1850. The girders consisted of two wrought iron rectangular tubes—each carrying a track for railroad trains. As steel rapidly replaced wrought iron for girder construction, the most common type of short span bridge used the riveted built-up plate girder, generally consisting of a web plate, side plates, flange angles, and flange plates (fig. 2–12). As steel plants developed larger rolling mills, it was possible to substitute rolled beams of I-sections for riveted girders. In the past 25 or more years, the use of welding has replaced riveted construction for spans too long for the rolled beam sections. Many of our modern highway bridges are either rolled beam or built-up girder structures (fig. 2–13). Instead of being constructed with one or more simple spans (fig. 2–14), they may consist of continuous beams of two or more spans (fig. 2–15), or they may consist of spans with cantilever overhangs supporting a simple suspended span (fig. 2–16).

d. *Reinforced Concrete.* Reinforced concrete construction combines the high compressive strength of concrete with the great tensile strength of the reinforcing steel. The reinforcing functionally replaces the portion of the concrete that is in tension. The first reinforced concrete slabs were made in France by Francois Hennebrique in 1880. The first reinforced concrete arch bridge in America, using the "Melan" system of I-beam reinforcement, was constructed in Cincinnati, Ohio, in 1894. During the first half of the 20th century, there were rapid advances in the use of reinforced concrete —first as simple span slab or beam bridges, then as rigid frames, and, finally, as prestressed concrete bridges, which first appeared after World War II (fig. 2–17). Prestressed concrete utilizes very high strength steel wire to apply an eccentric compressive force to the ends of the concrete beams to produce both axial compression and a bending moment of opposite sign to that of the design loads. This permits the structure to withstand much greater loads. Even when the superstructure of a bridge consists of steel trusses, beams, or girders, reinforced concrete plays an important role in the total structure. The abutments, wing walls, piers and deck are almost always made of reinforced concrete.

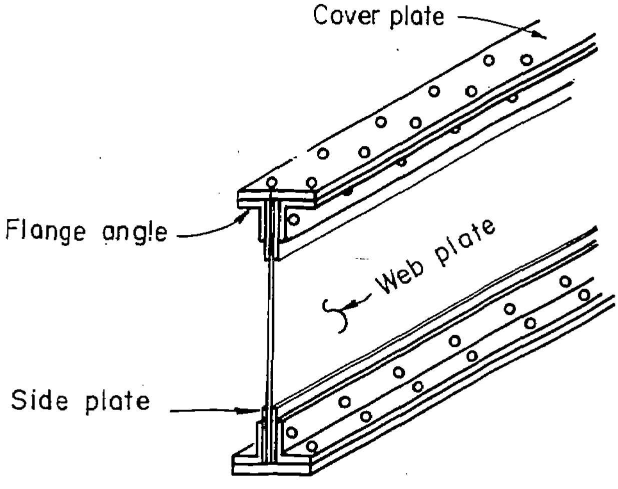
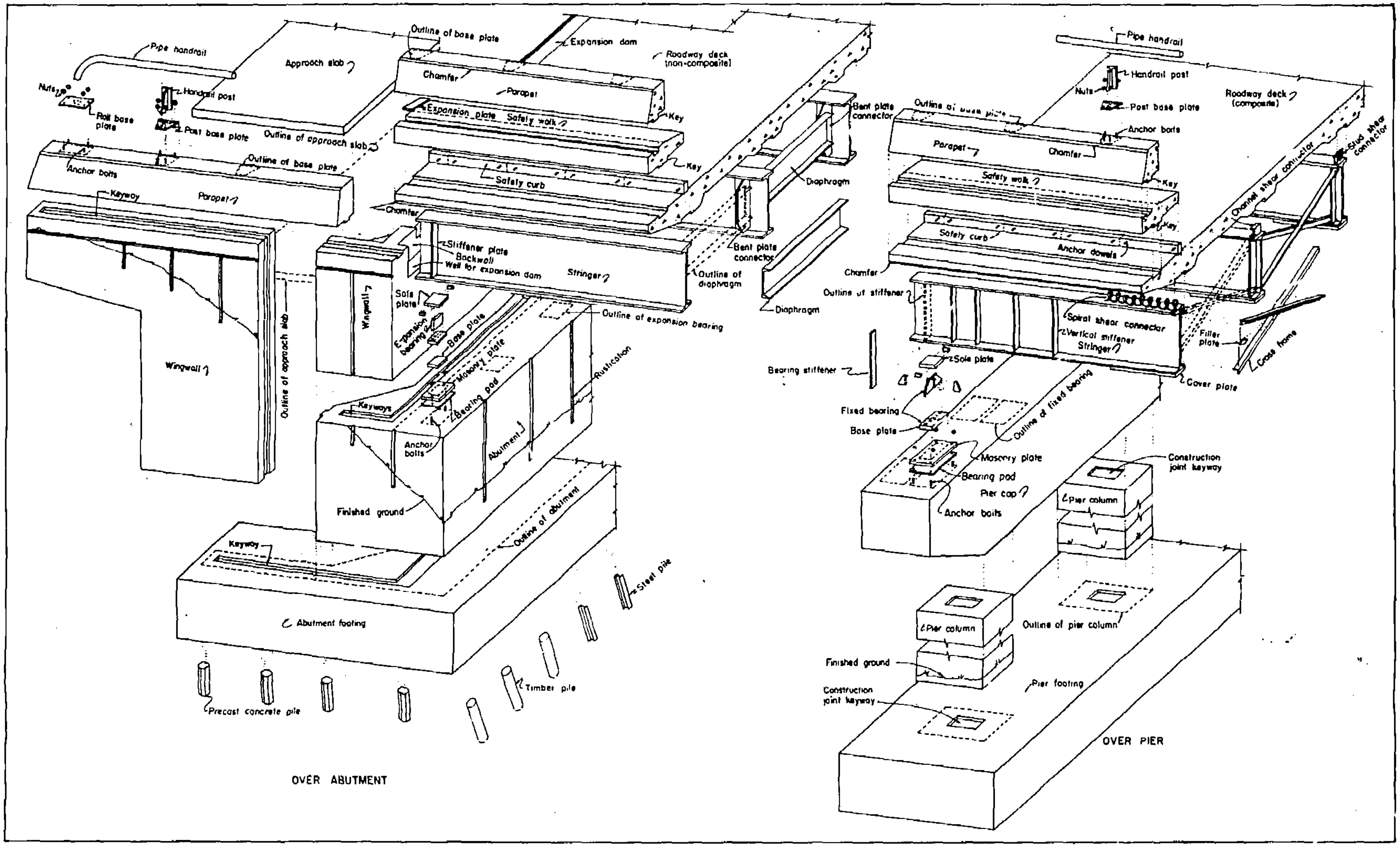



*Figure 2–12. Riveted plate girder*

e. *Twentieth Century Trends.* The steel truss continued to be the favorite for long span bridges well into the twentieth century, although concrete and masonry arches were also used extensively. For smaller spans, reinforced concrete slabs, "Tee" beams, wide flange steel, and built-up steel plate girders were all used. The development of parkways in the late 20's and early 30's generated another structure, the slender and attractive reinforced concrete rigid frame bridge. Stone-faced frames and small arches made highway bridges more attractive aesthetically. New York's Westchester Parkways and Connecticut's Merritt Parkway fur-




Courtesy of Clarkson and Clough Associates.

*Figure 2–13. Typical highway structure, exploded view.*

frames, damaged members, bearings, eyebars, and heavily corroded areas.

(2) *Suspension Bridges.* Sketches of suspension bridges should include, but not necessarily be limited to, anchorages, towers, cable bents, tower saddles, cable bands, suspender saddles, suspender connections, and stiffening truss connections. The critical areas on the stiffening trusses are the same as those listed under "Trusses" in the previous paragraph. It is particularly important to detail rocker bearings for towers and cable bents when they exist, the main cable cross section, heavily corroded members, cable bands, and cable wrappings.

(3) *Swing Spans.* Critical areas include truss details and connections, machinery, locks, electrical systems, controls, and girder details for girder type swing spans.

(4) *Bascule Spans.* The required details include counterweights, trunnion details, locks, machinery, buffers, cables, controls, corroded members, and details of connections of trusses and girders.

(5) *Vertical Lift Spans.* Critical areas include cables, anchorages for the cables, trunnions, sheaves, guides, limit switches, counterweights, counterweight balance chains, buffers, locks, machinery, electrical system, controls, corroded members, and bearings.

(6) *Cantilever Bridges.* On cantilever bridges, sketches are generally required for the hinges for the suspended span, rockers, bearings, the hold-down devices, if any, in the anchor spans, truss or girder details, and the corroded areas.

(7) *Bearing Devices.* Since bearing devices are a frequent source of trouble they should be inspected with particular care. Sketches should be made of each major bearing device showing its position, as in figure 3–6. Sketches should be made of any bearing that is not functioning properly.

(8) *Miscellaneous Sketches.* Sketches of fenders, dolphins, and aerial and navigational lighting will sometimes be required. Special terrain features or unusual slope protection or channel protection conditions will require sketches. Sketches may also be required for expansion devices.

(9) *Additional Sketches.* Since additional sketches may be required, it is a good practice to leave blank every third or fourth page for this purpose.

e. *Alignment.* A section of the notebook should be reserved for recording the horizontal and vertical alignment of the structure. Alignment should be checked for structures that are long, or show evidence of misalignment.

(1) *Substructure Drawings.* Drawings of each substructure unit should include a side elevation view and the two end elevation views. These sketches should be large enough so that the structure's horizontal and vertical alignment can be noted on the sketches after they have been determined.

(2) *Superstructure.* Sketches showing the plan and elevation views of the superstructure are necessary. The horizontal alignment should be noted on the plan view of the structure, and the vertical alignment of the elevation view.

f. *Environmental Features.* The environmental features that should be included are terrain features, stream profiles, high water elevation, spur dikes or other protection devices, slope protection, channel protection, and the channel location where it passes under the structure. In some instances it is desirable to show the channel condition upstream and downstream from the structure. The horizontal and vertical alignment of the approach roadway should also be shown.

g. *Underwater Investigation.* Plots of the contour of the stream bottom should extend to a radius of at least 100 feet from each pier. The purpose of the contour plots is to determine the extent of the scour. On the contour drawings, a plan view of the foundation should be included.

h. *Specialist Reports.* The final section of the notebook should include the reports of mechanical, electrical, or other specialists.

## Section 4. STRUCTURE EVALUATION

### 3–4.1 General.

A bridge is typically divided into two main units—the substructure, and the superstructure. For convenience the deck is sometimes considered as a separate unit. These basic units may be divided into structural members, which, in turn, may be further subdivided into ele-

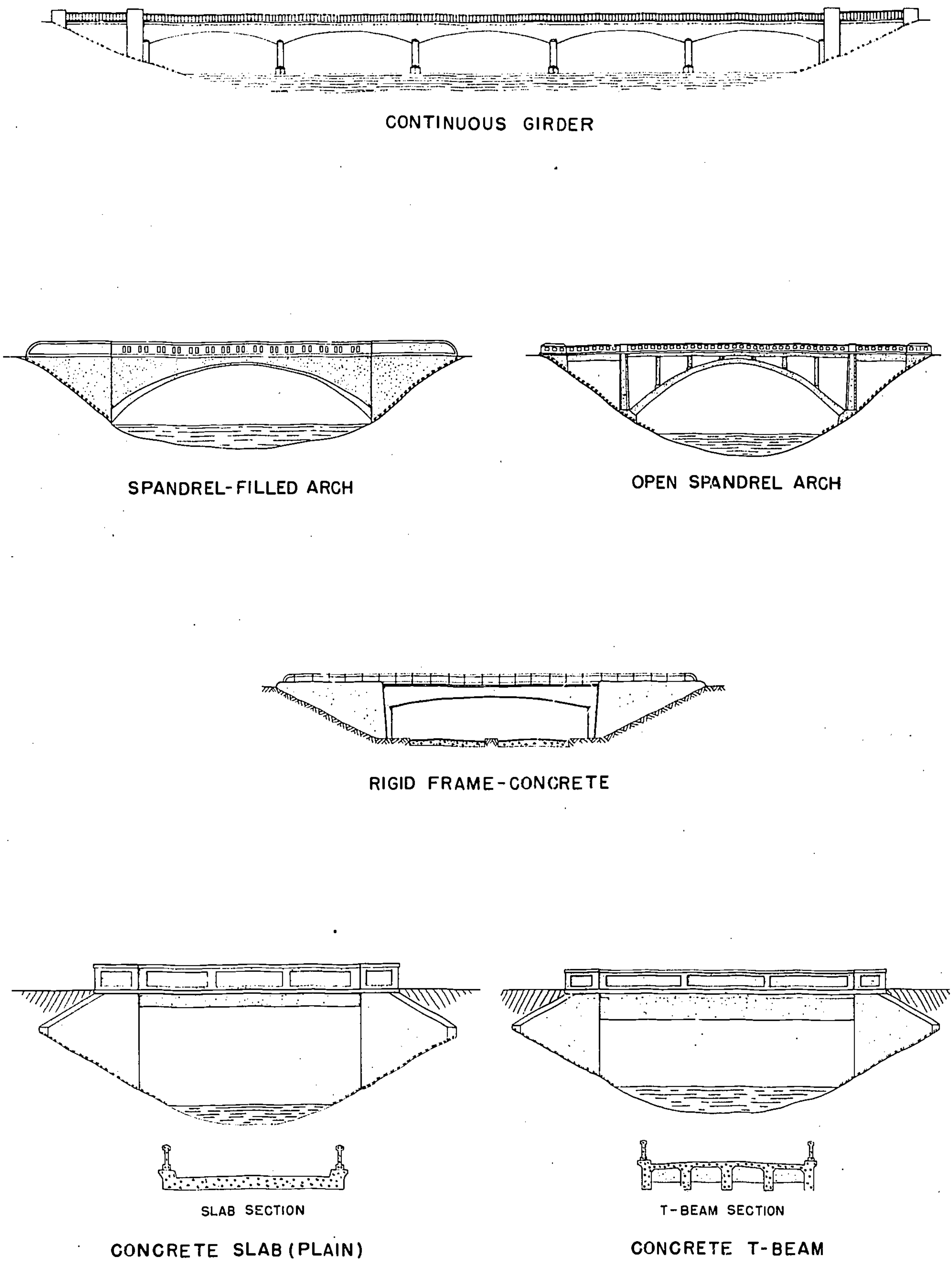



*Figure 2–17. Concrete bridges.*

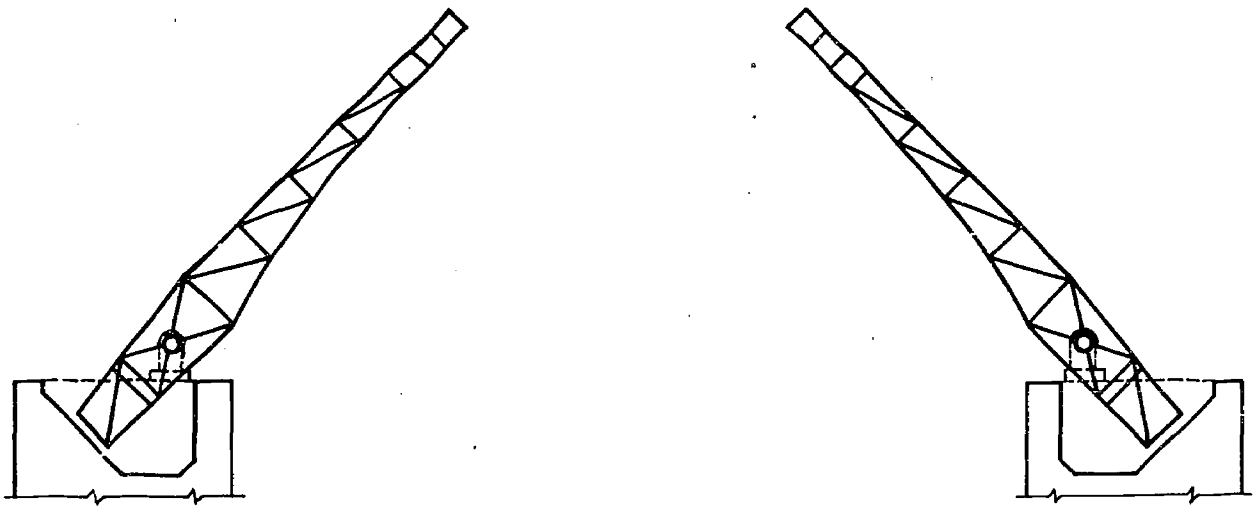


*Figure 2–18. Bascule bridge.*

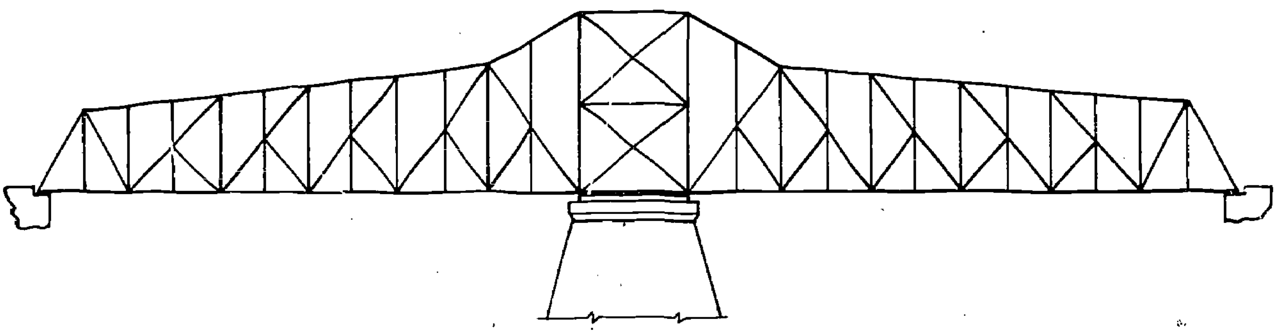


*Figure 2–19. Swing bridge.*

1,710 feet, was that of the great cantilever bridge across the Firth of Forth.) Probably the most famous suspension bridge is the Brooklyn Bridge built over the East River in New York City in 1883 by Washington Roebling. It had the longest suspension span in the world (1,595 feet), until the Williamsburg Bridge, also crossing the East River, with a span of 1,600 feet, was built almost 25 years later. Suspension bridge failures were common prior to the completion of the Brooklyn Bridge. The success of the Brooklyn Bridge led to the building of other long suspension spans, but the upper limit of span length seemed to have been reached until the Philadelphia-Camden Bridge over the Delaware River was opened in 1926 with a 1,750-foot span. In 1932, the George Washington Bridge was opened, its 3,500-foot span almost doubling the previous record. It was followed by the Golden Gate, Mackinac Straits, and the Verrazano Narrows bridges. The latter has the longest span between towers in the world, 4,260 feet. The destruction by aerodynamic forces of the original Tacoma Narrows bridge in 1940 led to considerable research into the effects of such forces, and to the strengthening of several major bridges. Although spans have more than doubled since 1883, the Brooklyn Bridge still stands as one of the great engineering achievements of our times. A typical modern day suspension bridge is depicted in figure 2–21.

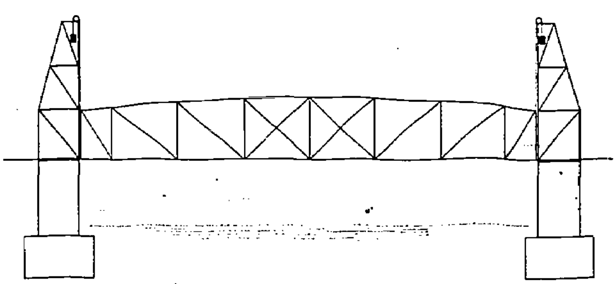


*Figure 2–20. Vertical lift bridge.*

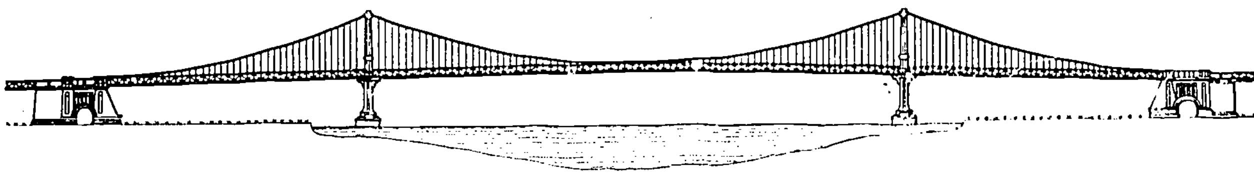


*Figure 2–21. Suspension bridge.*

## Section 2. ELEMENTS

### 2–2.1 Substructure.

a. *General.* The substructure includes those parts of the structure 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 multi-span structures there are also one or more piers (fig. 2–13). 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.

b. *Abutments.* The abutment is usually composed of a footing, a stem 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 retaining walls which keep the embankment soil around the abutment from spilling into the waterway or roadway which is being spanned. When U-shaped wing walls are used, parapets and railings are often placed on top of them.

c. *Piers.* 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 multi-legged piers, often with a cap binding the whole unit into a rigid frame. The pier cap is most noticeable on rigid frame piers and tee-piers. Starlings or pointed nosings are used on river piers to reduce the force of the water or ice against the piers.

### 2–2.2. Superstructure.

a. *General.* The superstructure includes all those parts of the structure supported by the substructure. It transfers the loads which must be carried to the bearings on the abutments or piers.

b. *Types.* The reinforced concrete slab bridge (fig. 2–17) has the simplest type of superstructure since the slab carries the load of the vehicle directly to the abutments or piers. On beam or girder bridges (figs. 2–11 and 2–17) the slab is supported on steel, concrete, or timber longitudinal members which, in turn, carry the loads to the abutments or piers (fig. 2–13). Finally, there is the superstructure consisting of the deck, a floor system, and two or more main supporting members.

c. *Superstructure Elements.*

(1) *Deck.* The bridge deck, either a concrete slab, timber planking, steel grid, or steel plate, supports the live load directly and distributes it to the floor system.

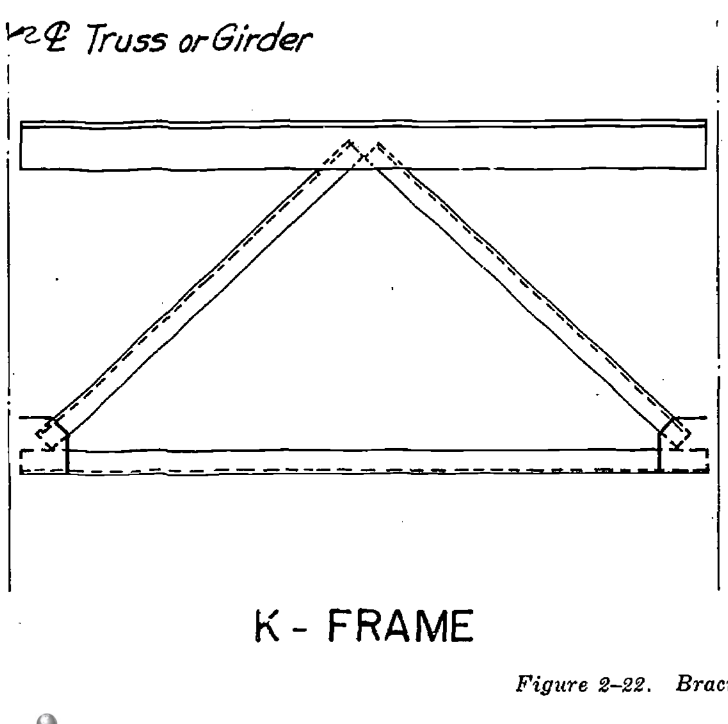
(2) *Floor System.* The floor system may consist of either closely spaced transverse floor beams or several longitudinal stringers carried by transverse floor beams. In floors of this type, the stringers are usually wide flange beams, while the floor beams may be plate girders, wide flange beams, or trusses. Where floor beams only are used, they may be either rolled beams or plate girders.

(3) *Main Supporting Members.* The main supporting members transmit all loads from the floor system to the supports at 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; steel or concrete rigid frames; arches of almost any mterial; or steel cables. Beams and girders are considered to be single elements while trusses have several identifiable parts. The chords, which are generally longitudinal members at the top and bottom of the truss, carry the tensile and compressive forces that make up the resisting moment of the truss, just as flanges d · for a beam. The verticals and diagnonals of a truss, often called the web members, carry the shear forces. Sloping chords also carry some of the shear forces. See Section 2-3 for a further discussion of tension, compression, moment, and shear.

(4) *Bracing*. The individual members of beam and girder structures are tied together with diaphragms and cross frames, while trusses are tied together with portals, cross frames, and sway bracing. Long structures, whether of the girder or truss type, also employ lateral bracing. Diaphragms and cross frames stabilize the beams or trusses and distribute loads between them. 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 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. Lateral bracing placed at the upper or lower chords (or flanges), or at both levels, transmits lateral forces (such as wind) to the supports. Although X-bracing has always been very popular, the increasing widths of structures, as well as aesthetic considerations have led to an increasing use of K-bracing (fig. 2-22). Figures 2-10 and 2-13 illustrate the location of these members in the bridge.

(5) *Miscellaneous*. Other components of the superstructure are the curbs, scuppers, sidewalks, parapets, railings, bearings, and expansion devices. Short span structures usually have



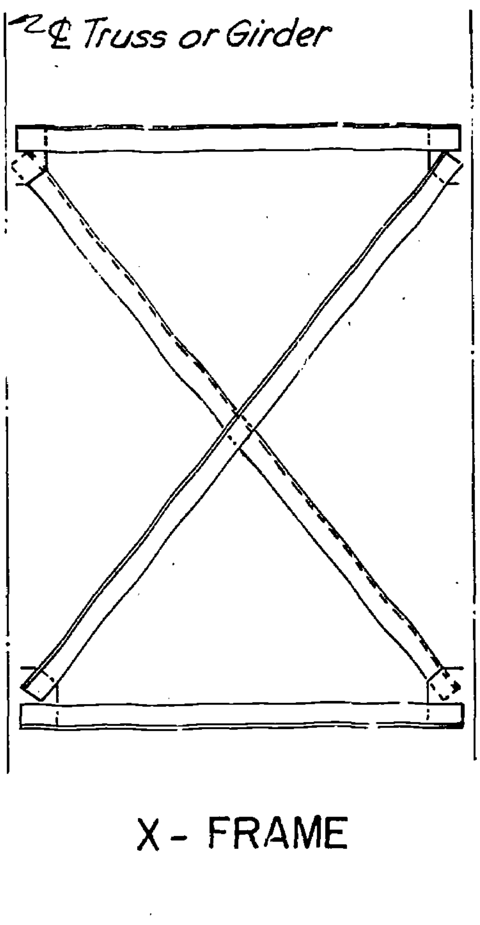




*Figure 2-22. Bracing.*

simple sliding plates on one of the bearings to accommodate changes in the length of the structure due to temperature changes whereas longer structures require rollers or rockers for this purpose. A short span structure usually has an open slot, a slot covered with a sliding plate, or a slot filled with elastomeric joint material to provide for expansion and contraction of the deck. However, long spans require elaborate finger joints to accommodate the greater amount of movement involved.

### *Section 3. MECHANICS*

#### 2–3.1 General.

Mechanics is that branch of physical science that deals with energy and forces and their relation to the equilibrium, deformation, or motion of solid, liquid, or gaseous bodies. Except for the action of movable bridges while being operated, the vibrations of large structures, and the like, the bridge inspector will primarily be concerned with statics, or that branch of mechanics which deals with solid bodies at rest or forces in equilibrium.

#### 2–3.2 Bridge Forces.

The solid bodies to be considered are the substructure and superstructure of the bridges to be inspected, while the forces exerted on them include various combinations of loads. The principal force is that of gravity acting on the weight of the structure itself (fig. 2–23), and on the vehicles (fig. 2–24), or on other live loads being carried by the structure. Other forces to be considered are those created by earth pressures (fig. 2–25), buoyancy or uplift on that portion of a structure which is submerged below water level (fig. 2–26); wind loads on the structure, vehicles, or live loads (fig. 2–27); longitudinal forces due to changes in speed of the live load or due to friction at the expansion bearings (fig. 2–28); temperature change (fig. 2–29), earthquake (fig. 2–30), stream flow and ice pressure (fig. 2–31); and , in the case of masonry structures, shrinkage and elastic rib shortening.

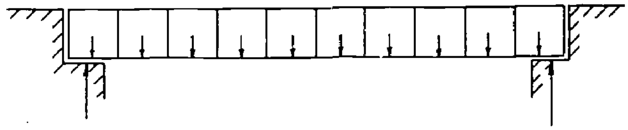


*Figure 2–23. Dead-load on simple span.*

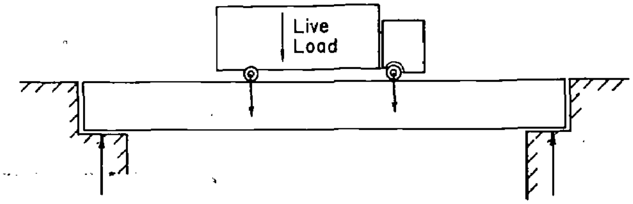



*Figure 2–24. Live load on simple span.*

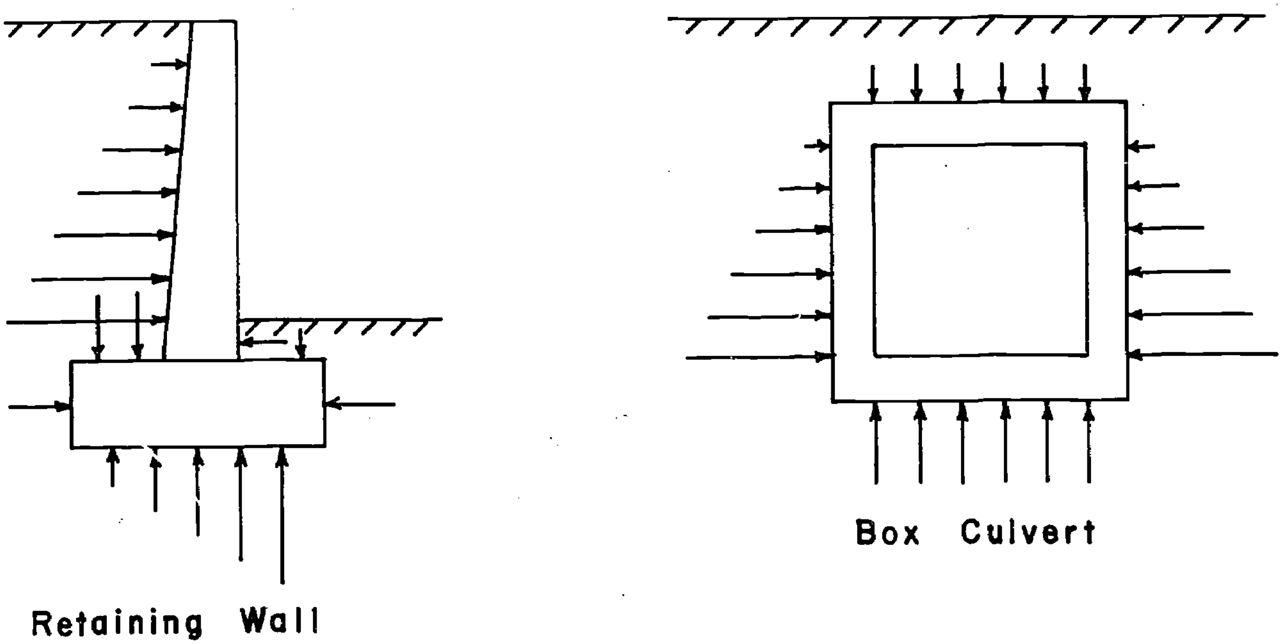



*Figure 2–25. Earth pressures.*

### 2-3.3 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 texts such as those listed in the Bibliography. Loads or forces acting upon members may be classified as axial, transverse, rotational and torsional. Figures 2-32 and 2-33 illustrate the action of these forces. Both axial and transverse forces are gravity forces and are expressed in pounds, kips (1000 lbs.), 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 2-33. The formula for axial stress is:

$$f = \frac{P}{A}$$

where: f = stress
P = load
A = cross-sectional area

a. *Tension.* A simple tension member could be one of the sub-vertical members of a through Baltimore or Petit truss (fig. 2-34). 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 sub-vertical 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

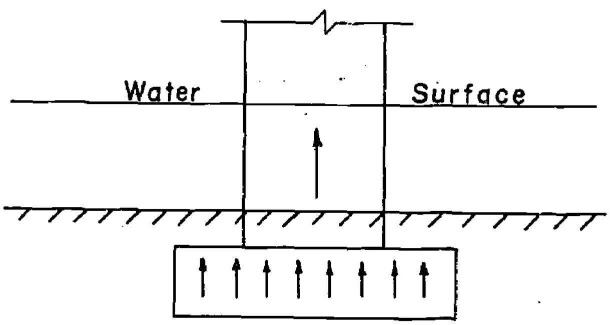



*Figure 2-26. Bouyancy on pier.*

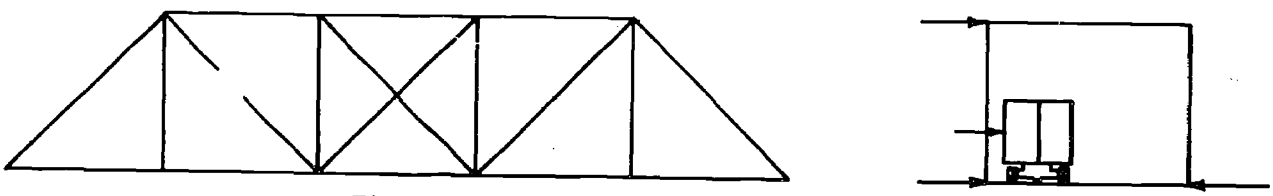


*Figure 2-27. Lateral wind load on truss and vehicle.*

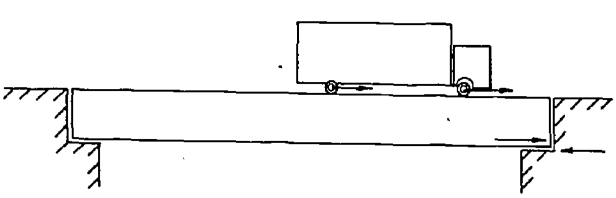


*Figure 2-28. Longitudinal force due to friction and live load.*

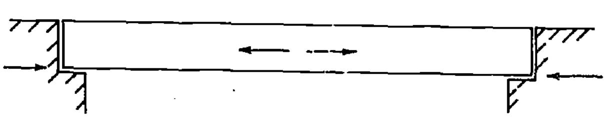


*Figure 2-29. Forces due to temperature rise.*

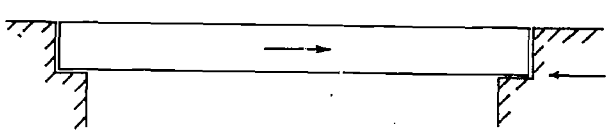


*Figure 2-30. Earthquake force (may be in any direction).*

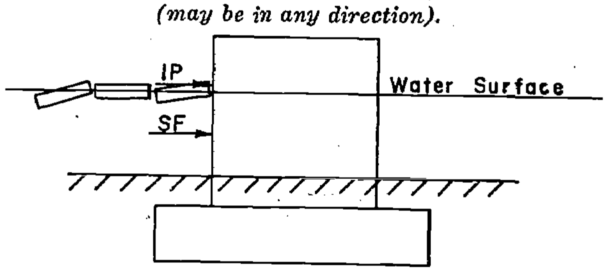



*Figure 2-31. Ice pressure and stream flow against pier.*

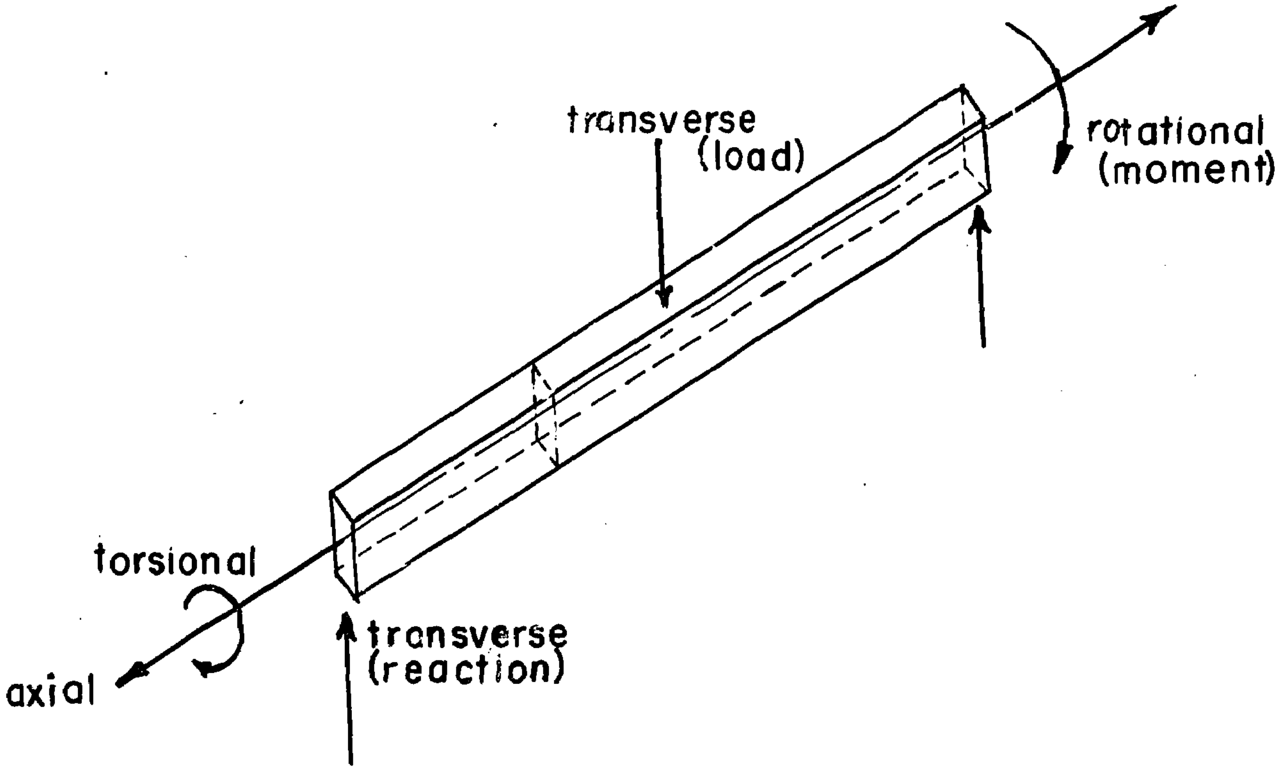



*Figure 2–32. Forces acting on members.*

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 (fig. 2–35). 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

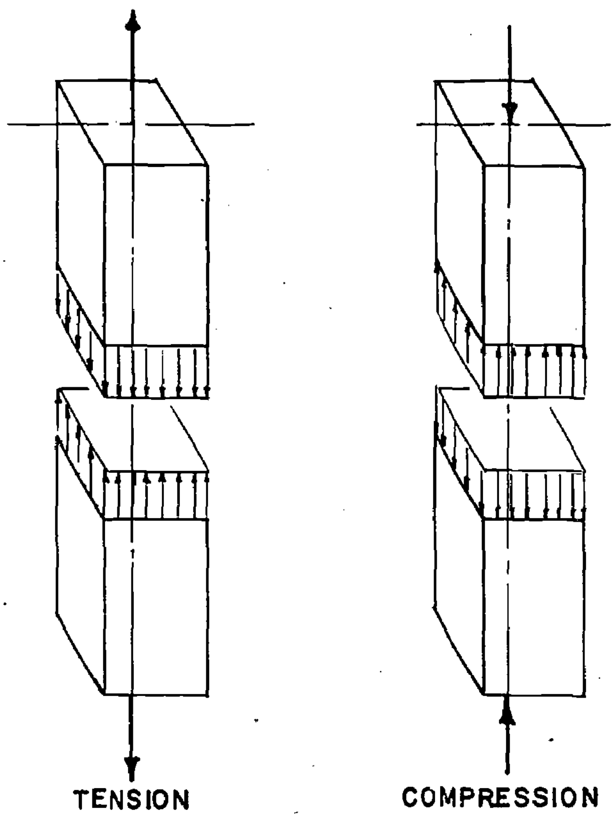



*Figure 2–33. Axial forces and stress distribution.*

side of the section. This scissor-like action is illustrated in figure 2-36. Oddly enough, the real shear stress produced by a transverse load is manifested in a horizontal shear stress (fig. 2-37 (a)). However, it is accompanied by a vertical shear stress of equal magnitude as shown in figure 2-37(b), which is an enlargement of the little element of figure 2-37(a). 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 for shear strength. The formula for vertical shear stress is:

$$f_v = \frac{V}{A_w}$$

where: $f_v$ = unit shear stress

$V$ = vertical shear due to external loads

$A_w$ = area of web.

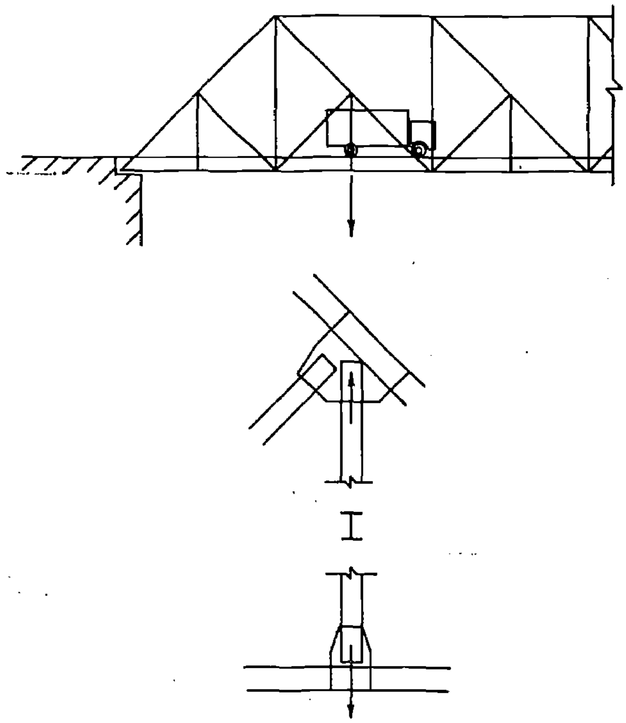


*Figure 2-34. Truss sub-vertical in tension.*

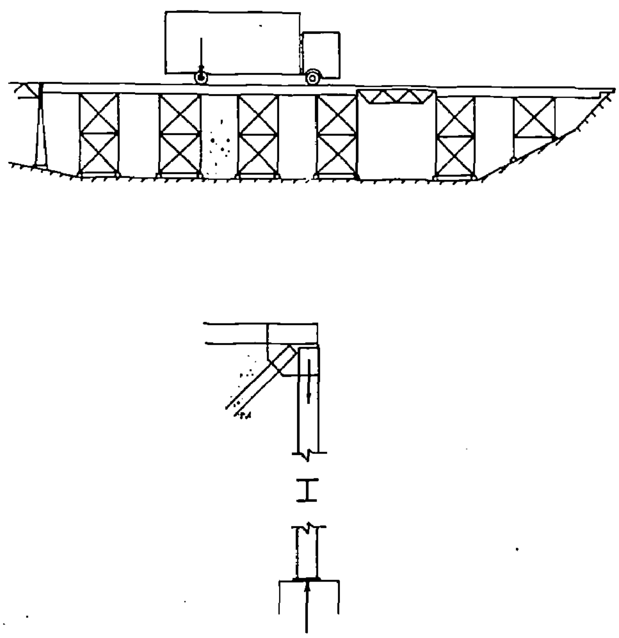


*Figure 2-35. Steel viaduct column in compression.*

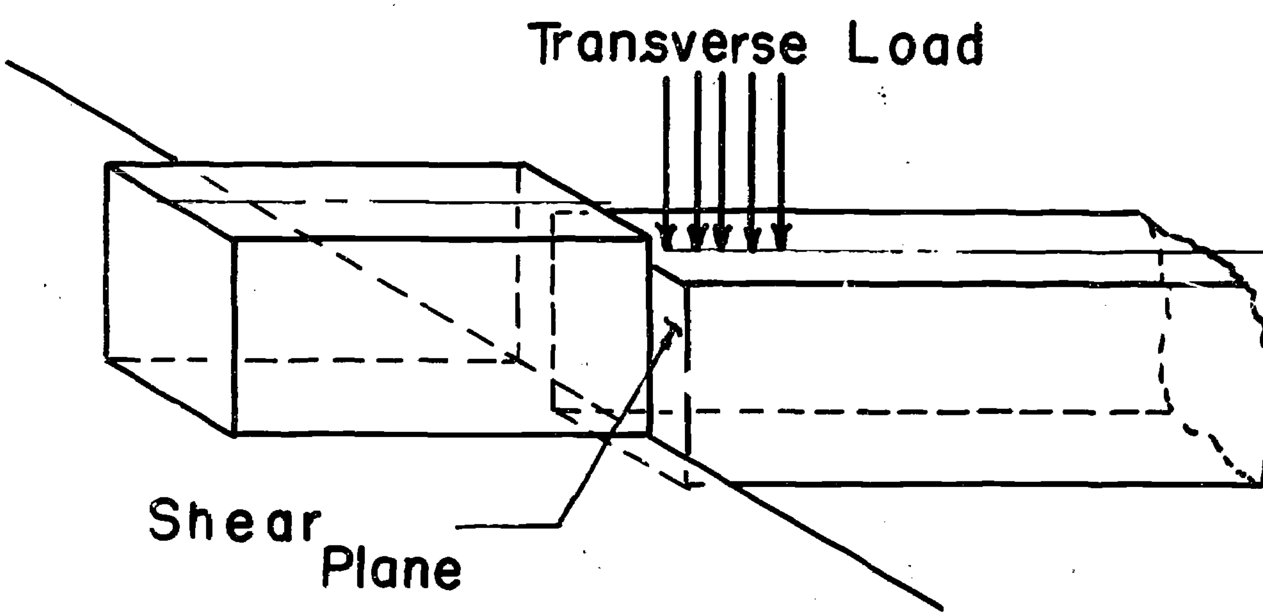



*Figure 2-36. Shear forces.*

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 2-38. 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) stresses are calculated by the following formula:

$$f_b = \frac{Mc}{I}$$

where: $f_b$ = bending stress

M = moment

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

I = moment of inertia—a property of the beam cross sectional area and shape.

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 (fig. 2-39). A moment producing this type of bending is considered positive. Positive moment is typical of vertical loads acting on simple beams.

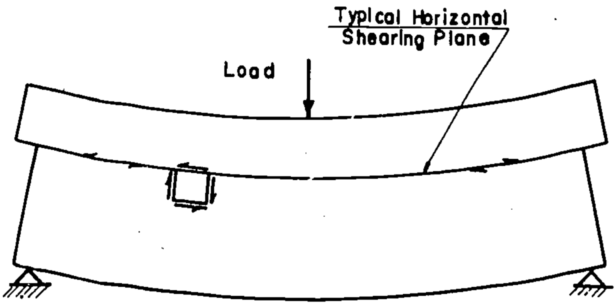



*Figure 2-37a. Horizontal shear.*

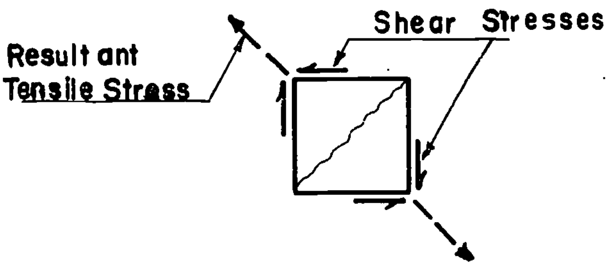



*Figure 2-37b. Shear stress and diagonal tension.*

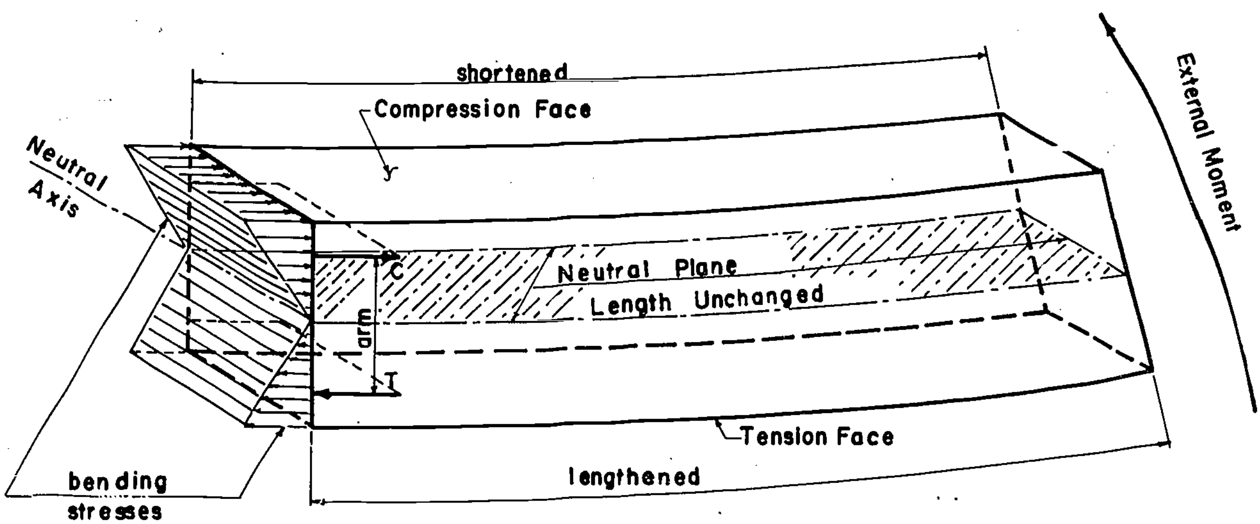



*Figure 2-38. Bending stress in a beam.*

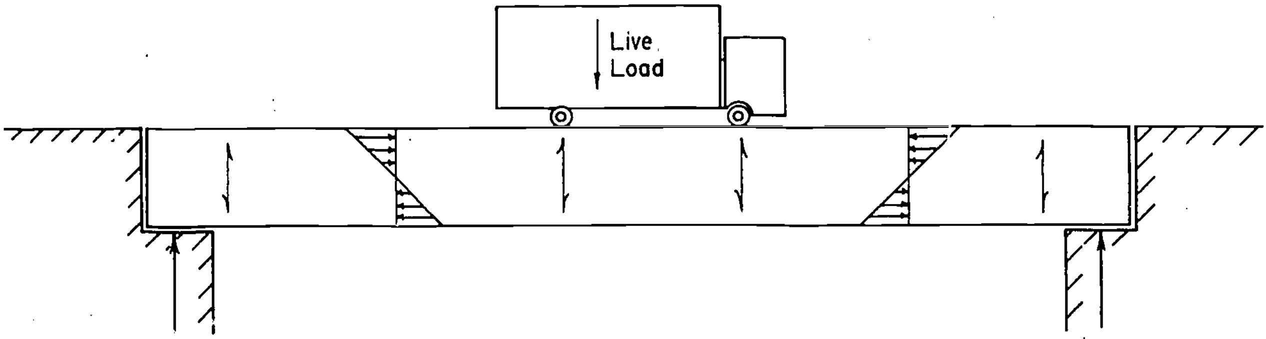



*Figure 2–39. Simple beam bending moment and shear.*

A continuous (over intermediate supports) beam is shown in figure 2–16. 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 (fig. 2–14) by an uplift force.

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.

### 2–3.4 Calculations.

a. *General.* In calculating the simple moments, shears, and axial forces of a beam or truss, the analysis is governed by the basic laws of statics:

$$\Sigma V = 0$$
$$\Sigma H = 0$$
$$\Sigma M = 0$$

where: V = vertical forces
H = horizontal forces
M = moments.

While such terms as "moment", "shear", and "reaction" may be new, their characteristics are implicitly used by the layman whenever he deals with a lever. Actually, the laws of the lever are special cases of beam statics. In making a rudimentary analysis of a beam, the points of primary interest are loads, reactions (support forces), shears, and moments. The following examples will indicate the procedure followed in determining the values of reactions, shears, and moments.

b. *Reactions.* Consider the beam in figure 2–40 (a). It has span L, load P, and cross sectional area of bd. The reactions due to load P will depend upon the size and location of the load, being inversely proportional to the distance between the load and the support. Using the law of the lever, the left reaction, $R_L$ is found to be equal to $P\frac{(L-a)}{L}$ in figure 2–40 (b). Where more loads than one are involved, the reactions may be calculated for each load separately and then totaled (fig. 2–40(c)). When a uniformly distributed load is used as in figure 2–43 (a), the load can be considered to be a series of point loads of w pounds applied every foot. The reactions may be obtained by calculating the total distributed load, W = wL, assuming it concentrated in a single load at the center of the total distributed load, and proceeding as before. The formulae for reaction may be summarized:

$$R_L = \frac{P(L-a)}{L}, \; R_R = \frac{Pa}{L} \text{ for concentrated load}$$

$$R_L = R_R = \frac{wL}{2} \text{ for uniformly distributed loads}$$

After calculating the end reactions of a beam, the results may be checked by use of the basic law of statics:

$$\Sigma V = 0$$

where there are no external horizontal or moment loads involved. Adding the load and reactions it can be seen that in figure 2–40 (b):

$$\Sigma V = 0 = P + R_L + R_R = -P + \frac{P(L-a)}{L} + \frac{Pa}{L}$$

$$V = -P + \frac{P(L-a+a)}{L} = -P + P = 0$$

For computational purposes, forces upward (↑) and to the right (→) and clockwise moments (↻) are taken as positive. This same relationship is used in finding internal vertical shears.

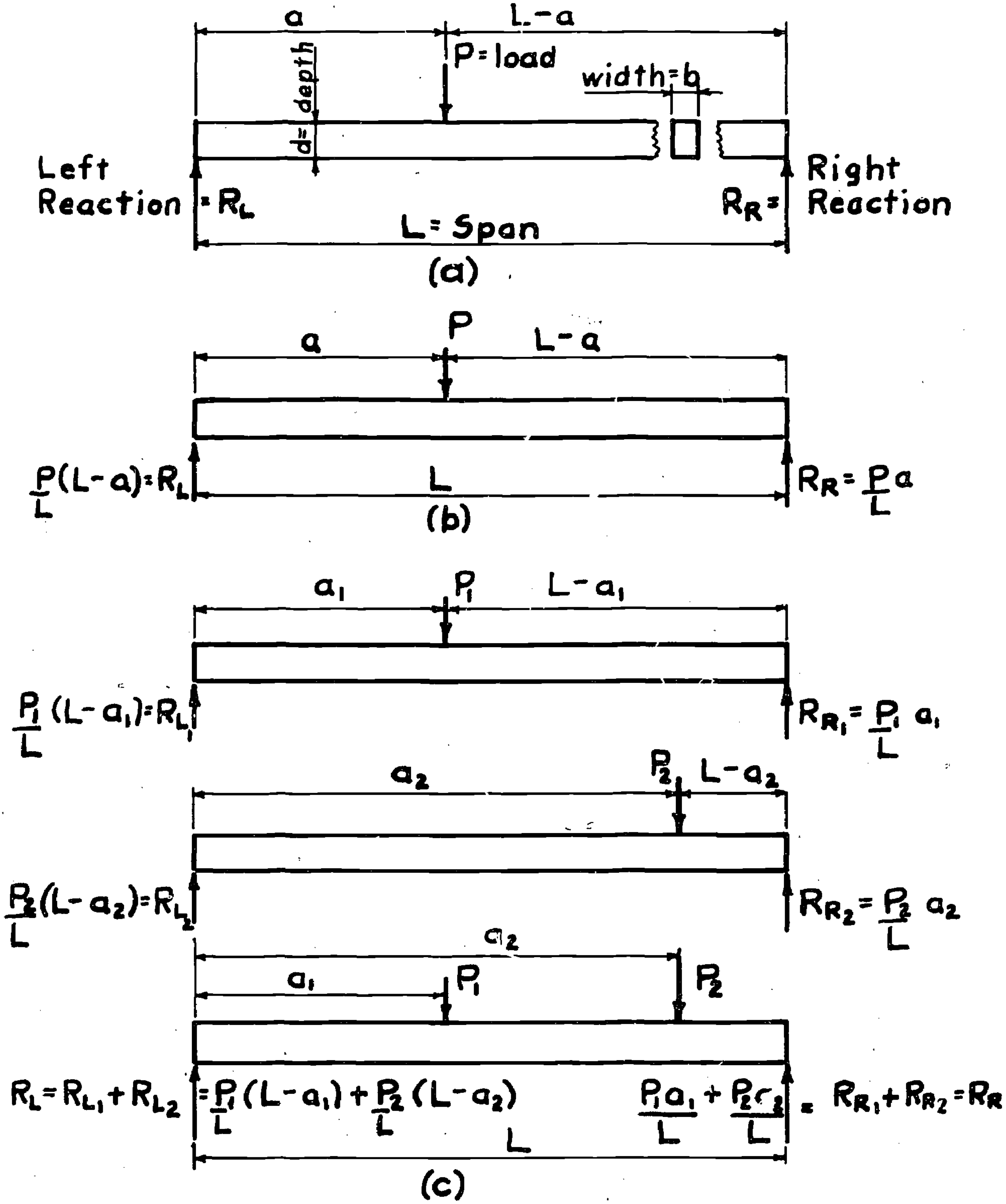



*Figure 2-40. Reactions with concentrated load applied.*

c. *Vertical Shear.* Vertical shears may be obtained in a somewhat similar fashion since reactions are actually the end (and the maximum) shears on a beam. If imaginary (or virtual) cuts are made in several places in the beam of figure 2–40 (b), say at $x_1$ and $x_2$ as shown in figure 2–41 (a), it is divided into three "free bodies". A free body is a portion of a loaded member or structure which is hypothetically separated from the rest of the member or structure, with the sole result of changing internal forces to external forces. If a real beam were divided into three parts, load P would be carried completely by new reactions at $x_1$ and $x_2$, and the original reactions $R_L$ and $R_R$ would become zero. However, the free body concept requires the use of equal and opposite reactions at $x_1$ and $x_2$, allowing load P to reach reactions $R_L$ and $R_R$. The important thing, however, is that these intermediate reactions are actually the internal vertical shears. Therefore, considering free body (1) in figure 2–41 (a) the shear at $x_1$ is found from the V = 0 law, i.e.,

$$\Sigma V = 0 = R_L - V_1$$

$$V_1 = R_L = \frac{P(L-a)}{L}$$

where: $V_1$ = shear force @ $x_1$, i.e., a vertical force transverse to a horizontal beam.

The astute observer will note that this creates an unbalanced moment of $\frac{P(L-a)}{L}x_1$, but consideration of that aspect will be deferred. When checking shear at $x_2$, the free bodies [1] and [2] are usually combined as in figure 2–41 (b), since there is now no need for the joint at $x_1$. (However, using shear $V_1$, free body [2] alone would serve to determine $V_2$.) Again using $\Sigma V = 0$,

$$\Sigma V = 0 = \frac{P(L-a)}{L} - P + V_2$$

$$V_2 = \frac{P - P(L-a)}{L} = \frac{PL - PL + Pa}{L} = \frac{Pa}{L}$$

It will be noted that $V_2$ could have been calculated from free body [3] also. Once again, we note the presence of an unbalanced moment and defer its consideration. A similar approach is used in dealing with distributed loads. First, determine the reaction as done above, then, cut the beam at point $x_1$ creating free body [1] (fig. 2–43 (b)). The total distributed load on this free body is $wx_1$ and it is concentrated at the center of the free body. Again:

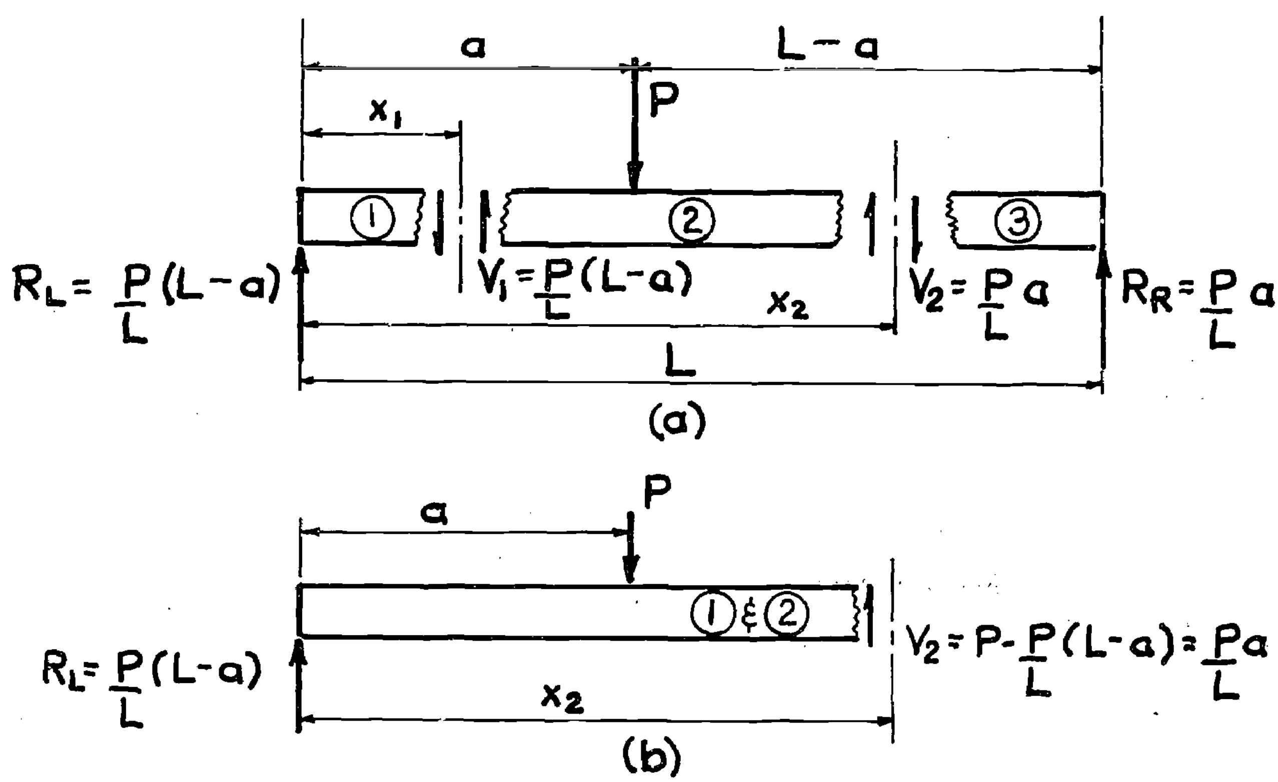



*Figure 2–41. Shear forces with concentrated load applied.*

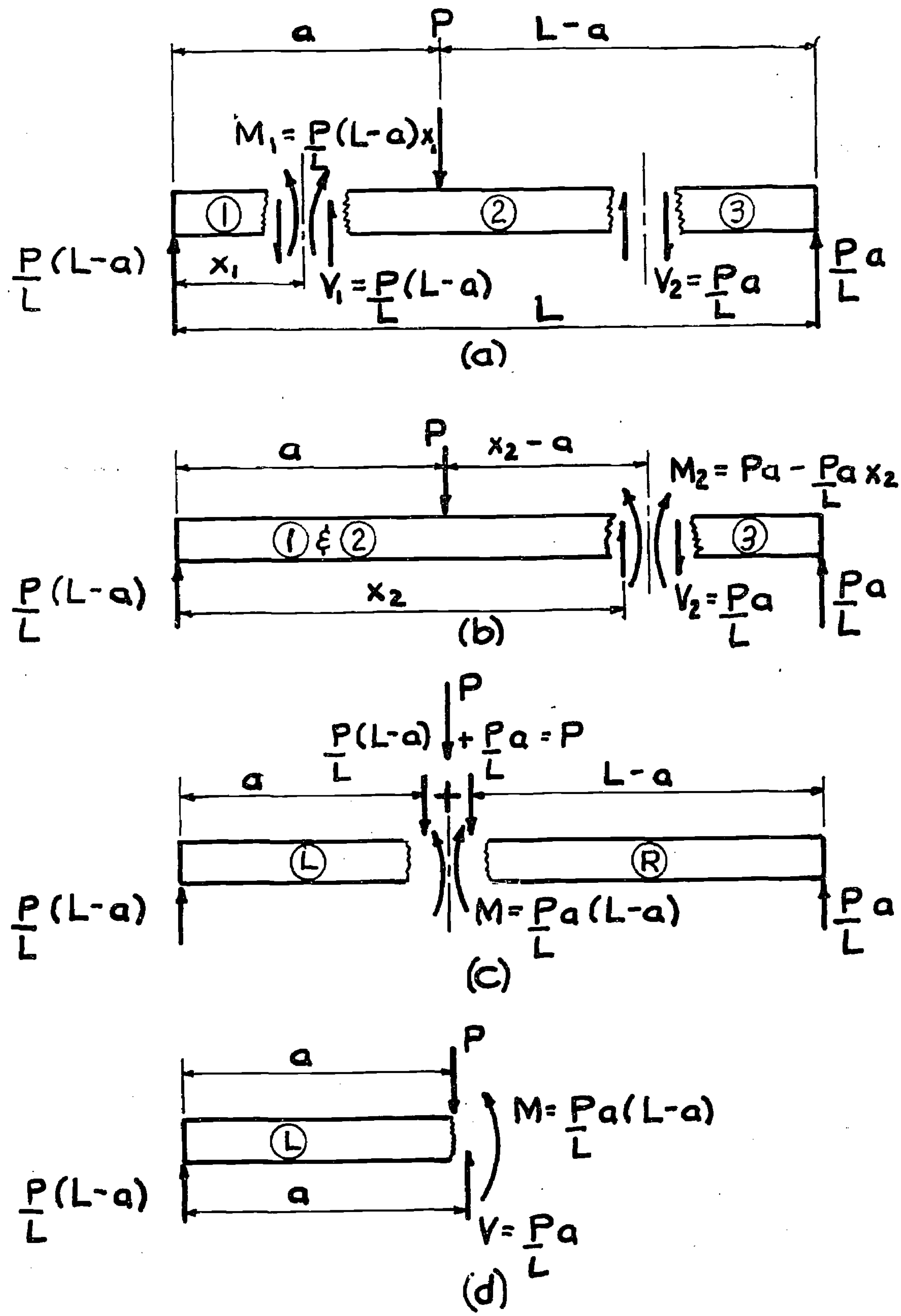



*Figure 2–42. Moments with concentrated load applied.*

$$\Sigma V = 0 = R_L - W_1 - V_1 = \frac{wL}{2} - wx_1 - V_1$$

$$V_1 = \frac{wL}{2} - wx_1 = w\left(\frac{L}{2} - x_1\right)$$

In this case, $V_1$ may be a minus value, if the reaction is less than $wx_1$. This would mean that the direction of the shear is opposite to that assumed, and actually is an upward force.

d. *Moments*. In the above determination of shears, the presence of unbalanced moments acting on the free bodies was noted. These moments are important since the beam must be designed to resist them. Figure 2–42 (a) shows the same beam with free bodies [1], [2], and [3]. In free body [1], applying M = 0, it is obvious that an internal moment at $x_1$ is required. Moment $M_1$ must be opposite in direction to the moment formed by the reaction $R_L$ and the vertical shear $V_1$. These forces create a moment about the left support of $\frac{P(L-a)}{L}x_1$.

$$\therefore \Sigma M_{Left} = 0 = V_1x_1 - M_1 = \frac{P(L-a)}{L}x_1 - M_1$$

$$\therefore M_1 = \frac{P(L-a)}{L}x_1$$

In figure 2–42 (b), the moment is calculated at $x_2$, by again taking moments about the left support ($x_2$ could have been used equally well):

$$\Sigma M_{Left} = 0 = Pa - V_2x_2 - M_2 = Pa - \frac{Pa}{L}x_2 - M_2$$

$$M_2 = Pa - \frac{Pa}{L}x_2 = Pa\left(1 - \frac{x_2}{L}\right)$$

The distributed load is handled in a similar manner (fig. 2–43 (c)). Taking moments about the left support:

$$M_1 = 0 = wx_1(\tfrac{1}{2}x_1) - V_1x_1 - M_1 = wx_1(\tfrac{1}{2}x_1) - \left(wx_1 - \frac{wL}{2}\right)x_1 - M_1 = \frac{wx_1^2}{2} - wx_1^2 + \frac{wLx_1}{2} - M_1 = \frac{wLx_1}{2} - \frac{wx_1^2}{2} - M_1$$

$$\therefore M_1 = \frac{wLx_1}{2} - \frac{wx_1^2}{2} = \frac{wx_1}{2}(L - x_1)$$

In the special case where $x_1 = \frac{L}{2}$

$$M = \frac{w}{2}\left(\frac{L}{2}\right)\left(L - \frac{L}{2}\right) = \frac{wL}{4}\left(\frac{L}{2}\right) = \frac{wL^2}{8}$$

The final step in moment calculation will be calculation of the moment under a load. This is a special case of the foregoing calculations, but an important one, since maximum moment is usually at a load point. In figure 2–42(c), P is divided into two parts proportioned to the two reactions. The moment under the load, from moments taken about the left support, is

$$\Sigma M_{Left} = 0 = \frac{P(L-a)}{L}a - M = 0$$

$$M = \frac{Pa}{L}(L-a)$$

If $a = \frac{L}{2}$, the special case of a point load at mid span exists and

$$M = \frac{P}{L}\left(\frac{L}{2}\right)\left(L - \frac{L}{2}\right) = \frac{P}{2}\left(\frac{L}{2}\right) = \frac{PL}{4}$$

This calculation can also be made about the left support. It may also be demonstrated as in figure 2–42 (d):

$$\Sigma V = 0 = R_L - P + V = \frac{P}{L}(L-a) - P + V = -\frac{Pa}{L} + V$$

$$\therefore V = \frac{Pa}{L}$$

$$\Sigma M_{Left} = 0 = \left(P - \frac{Pa}{L}\right)a - M = \left(\frac{PL - Pa}{L}\right)a - M = \frac{Pa}{L}(L-a) - M$$

$$\therefore M = \frac{Pa}{L}(L-a)$$

e. *Shear and Moment Diagrams.*

(1) In making calculations for checking a beam, it is often convenient to use shear and moment diagrams. A shear diagram for a beam is a curve, or graphic plot, in which the abscissae represent distances along the beam, and the ordinates represent the vertical shears for the sections at which the ordinates are drawn. The moment diagram for a beam is also a curve in which the abscissae represent distances along the beam, but the ordinates represent the bending moments for

the section at which the ordinates are drawn. In constructing these diagrams certain conventions and relationships are useful. The relationships will not be derived here. Those who are interested can find both derivation, proof, and more detailed instructions in standard texts on structural analysis and design.

(2) The sign conventions for shear diagrams will be similar to that maintained in paragraph 2–3.4.b, i.e., forces upward (↑) and to the right (→) are considered positive. Shears are positire when the external forces or loads produce a relative upward movement of the portion of the beam to the left of the section under consideration. The remaining part of the beam (on the right of the section) will have a relative downward movement. In figure 2–36, the shear at the illustrated section is positive by this convention. In figure 2–41(a), the shear is positive at $x_1$, and negative at $x_2$. For the moment diagram, the moment convention will be that mentioned in paragraph 2–3.3.d. A positive moment bends a beam into a concave upward shape, while a negative moment causes a concave downward curvature (fig. 2–44). It may be observed that all moments shown in

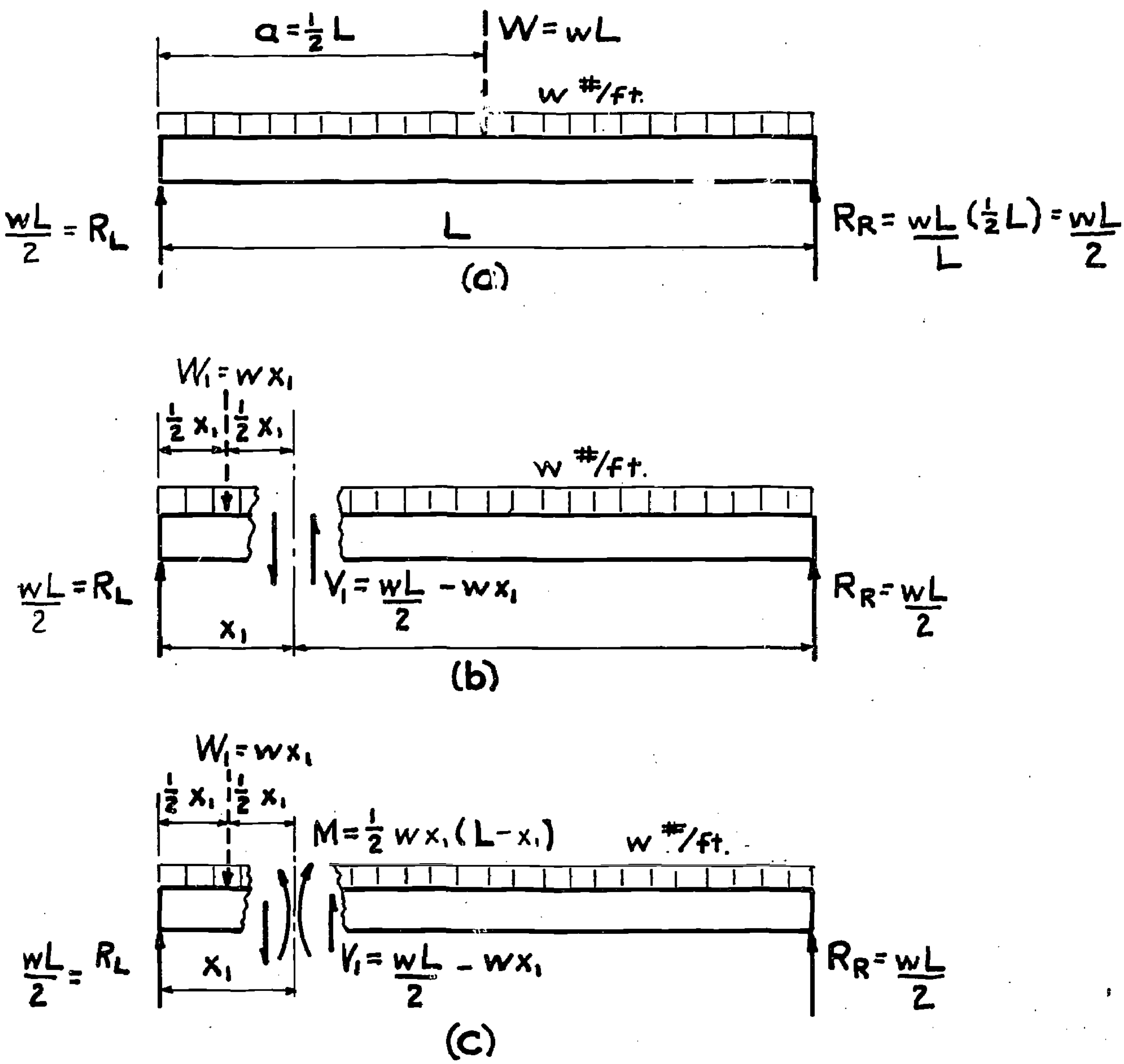
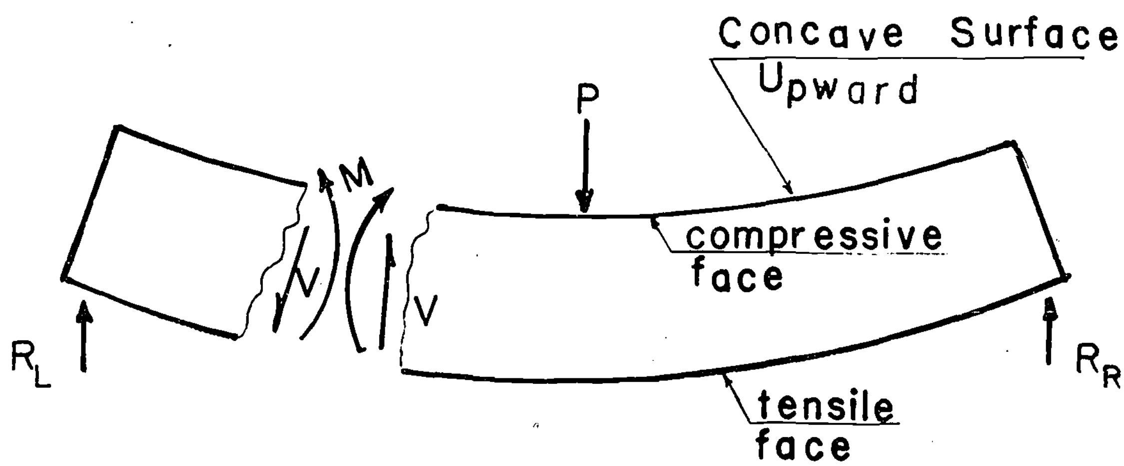
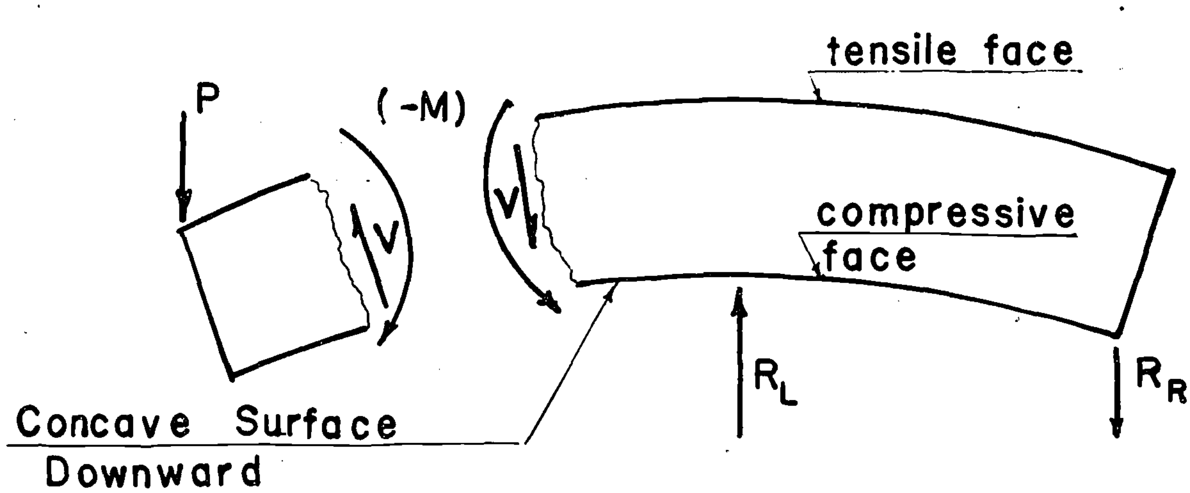



*Figure 2–43. Reactions, shears, and moments with uniform load applied.*

figures 2–38, 2–39, 2–40, 2–41, 2–42, and 2–43 are positive. As noted earlier, the concave upward slope of the positive moment is due to compressive shortening of the portion of the beam above the neutral axis, and tensile elongation of the beam below the neutral axis. (Negative moment is just opposite.) The clockwise (↷) positive convention for moment given in paragraph 2–3.4.b should be used for calculations only. In plotting moments, it is customary to plot moments on the surface of the beam which is in tension. This gives an excellent graphic representation and helps to avoid errors in sign.

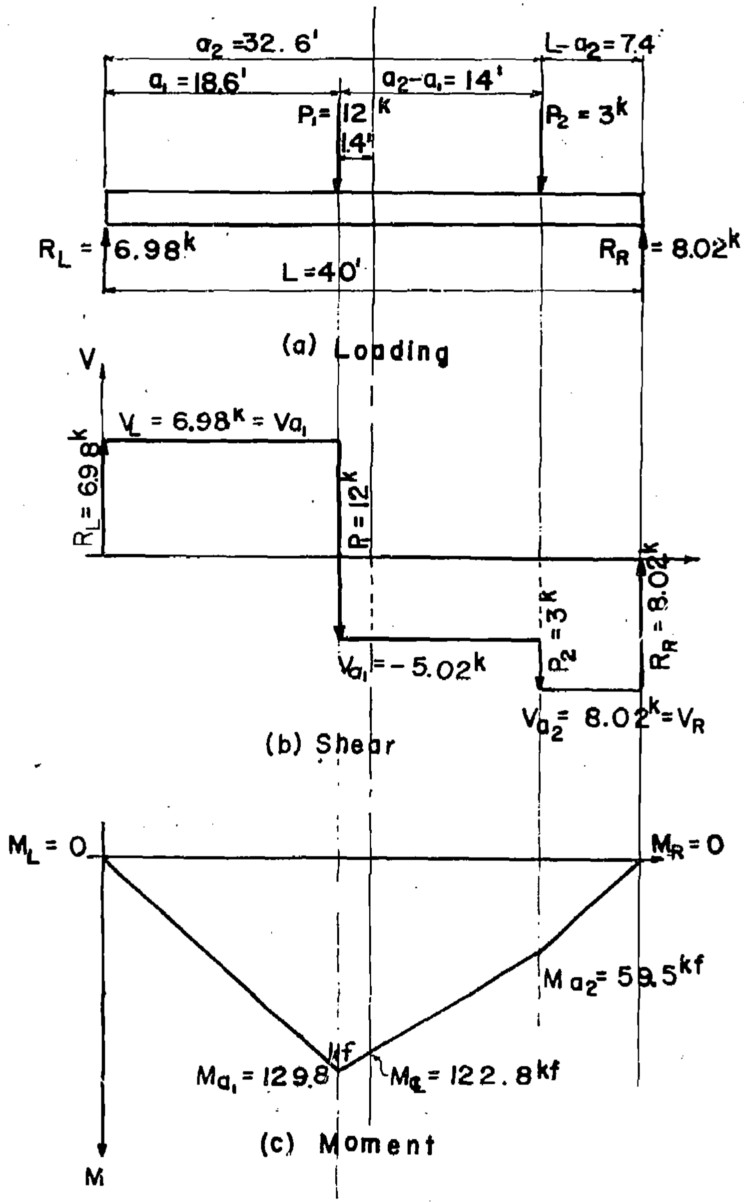



(a) Positive Moment




(b) Negative Moment

*Figure 2–44. Moment convention. The curvature is greatly exaggerated for clarity. The shear forces are actually nearly parallel to the loads.*




$R_L = \frac{P_1}{L}(L - a_1) + \frac{P_2}{L}(L - a_2)$

$R_L = \frac{12^k}{40'}(21.4') + \frac{3^k}{40'}(7.4') = 6.42^k + 0.56^k = 6.98^k$

$R_R = \frac{P_1 a_1}{L} + \frac{P_2 a_2}{L} = \frac{12^k}{40'}(18.6') + \frac{3^k}{40'}(32.6') =$

$R_R = 5.58^k + 2.44^k = 8.02^k$

$V_L = R_L = 6.98^k$

$V_{a_1} = V_L + P_1 = R_L + P_1$

$V_{a_1} = 6.98^k - 12^k = -5.02^k$

$V_{a_2} = V_{a_1} + P_2 = R_L + P_1 + P_2$

$V_{a_2} = -5.02^k - 3^k = -8.02^k$

$V_R = V_{a_2} = -8.02^k$

$V_R + R_R = -8.02^k + 8.02^k = 0$

$M_{a_1} = V_L a_1 = 6.98^k(18.6') = 129.8^{kf}$

$M_{℄} = M_{a_1} + V_{a_1}(1.4')$

$M_{℄} = 129.8^{kf} - 5.02^k(1.4') = 122.8^{kf}$

$M_{a_2} = M_{℄} + V_{℄}(12.6)$

$M_{a_2} = 122.8^{kf} - 5.02^k(12.6') = 59.5^{kf}$

$M_R = M_{a_2} + V_{a_2}(L - a_2)$

$M_R = 59.5^k - 8.02^k(7.4') = 59.5^k - 59.5^k$

$M_R = 0$

*Figure 2–45. Shear and moment diagrams for concentrated loads.*

(3) The following simple relationship provides an automatic and easy way of computing shear and moment diagrams.

(a) The shear ordinate at any section is equal to the algebraic sum of all the vertical loads to the left of the given section.

(b) The moment ordinate is equal to the net area under the shear diagram for the portion of the beam to the left of the section.

(4) Shear and moment diagrams and calculations for both concentrated and distributed loads are illustrated in figures 2–45, 2–46, and 2–47. While these figures are intended to be self-explanatory, some clarification may be helpful. Beam and loadings similar to those in figures 2–40 (c) and 2–43 (a), but with specific numerical values, are used in figures 2–45 and 2–46. The loading, in which $P_1 = 12^K$, $P_2 = 3^K$, and $w = 1k/ft$, is comparable to that of the wheels of an H–15 truck and to the dead load of a steel beam bridge. The dimensions are also similar to what would be encountered in a bridge beam design. In figure 2–45(a), the reactions are calculated using formulae developed in figure 2–40 (c). As a check on the calculation,

$$V = 0 = R_L + R_R - P_1 - P_2 = 6.98 + 8.02 - 12 - 3 = 0$$

Consistent with the nature of a shear load, the end shear $V_L$ occurs an infinitesimal distance to the right of the support. However, the algebraic operation treats it as being at the supports.

(5) Now calculations of the shear diagram can begin. The leftmost load is the left reaction, which is equal to the end shear:

$$V_L = R_L = 6.98^K.$$

The upward end of the reaction vector R marks the first point on the shear diagram ($X = 0$, $V = 6.98^K$). Since no further vertical forces are encountered until $P_1$ is reached, the vertical shear is constant and the shear diagram is a horizontal line extending to the right for 18.6′. At this point on the beam, $P_1$ is applied as noted by the downward $12^K$ load vector. Note that $P_1$ takes the shear diagram across the X-axis and changes the shear to a negative value. Here, the fine distinction as to application of a shear force at an infinitesimal distance from the section is important. Just to the left of $X = a_1$, the shear is positive and equal to $6.98^K$. Just to the right of $X = a_1$, the shear is negative and equal to $-5.02^K$,

$$V_{a_1} = R_L = 6.98^K, \text{ and}$$

$$V_{a_1} = R_L + P_1 = 6.98^K - 12.00^K = -5.02^K$$

The algebraic difference of the two shears should equal the concentrated load, $P_1$. The shear remains unchanged for the next 14′; therefore, the shear diagram from $X = 18.6'$ to $X = 32.6'$ is a horizontal line at $V = -5.02^K$. At $X = a_2 = 32.6'$, the presence of load $P_2$ is marked by a negative vector of $3^K$. This causes a further increase in negative shear since:

$$V_{a_2} = V_{a_1} + P_2 = R_L + P_1 + P_2 = 6.98^K - 12^K - 3^K$$

$$V_{a_2} = V_{a_1} + P_2 = 6.98^K - 12^K - 3^K = -8.02^K$$

While there are two different values of $V_{a2}$ at $X = a_2$, there is not as much concern since the sign does not change. In such situations, the larger numerical value is of primary concern. Since there are no more external vertical loads to cope with, the shear diagram continues horizontally at $-8.02^K$ to the right support. The right reaction of $8.02^K$ is equal and opposite to the shear; therefore, the diagram is correctly plotted. The reaction vector $R_R = 8.02^K$ closes the shear diagram and satisfies the requirements of static equilibrium: $\Sigma V = 0$. The general formula for shear at any point, X, on a beam may be given as follows:

$$V_X = R_L + \Sigma P_X$$

where: $V$ = vertical shear at X

$R_L$ = left reaction

$\Sigma P_X$ = algebraic sum of all external loads acting on the beam between the left reaction and section X.

(6) While the moment curve values can be calculated directly from the loads, calculation of the moment diagram from the shear diagram provides better visualization and helps to avoid errors. In figuring moments, the second principle, mentioned in subparagraph (3)(a) above will be used, i.e., moment value is equal to the net area under the corresponding length of shear curve. Since the beam is simply supported, the moment is zero (0) at the supports.

$$M_L = 0$$

Calculating the moment at $X = a_1 = 18.6'$, (under load $P_1$), the area under the shear diagram is $V_L(a_1) = 6.98^K(18.6') = 129.8^{KF}$

$$\therefore M_{a_1} = 129.8^{KF}$$

The moment at $X = a_2 = M_{a_1} + V_{a_1}(a_2 - a_1)$

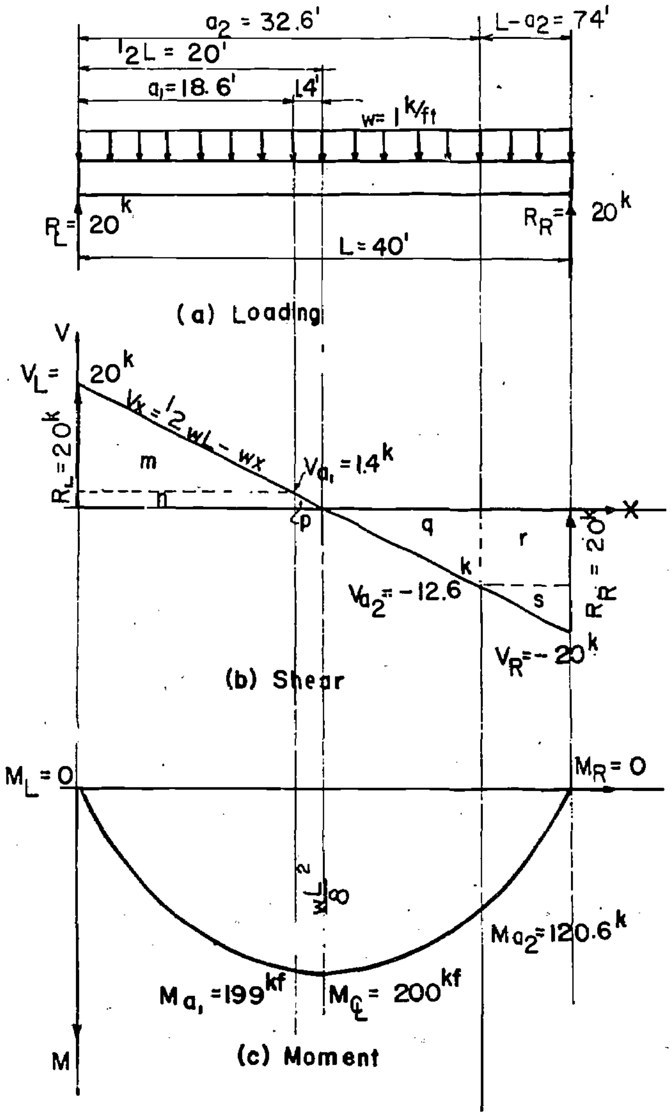
$$M_{a_2} = 129.8^{KF} - 5.02^{K}(14')$$
$$= 129.8^{KF} - 70.3^{KF} = 59.5^{KF}$$

The $-5.02^{K}(14')$ will be recognized as the area under the shear curve between $X = a_1$ and $X = a_2$. Since it is a negative shear area, the moment is reduced. Calculating the last area under the shear diagram between $X = a_2$ and $X = L$:

$$M_R = M_{a_2} + V_{a_2}(L - a_2) = 59.5^{KF} - 8.02^{K}(7.4')$$
$$= 59.5^{KF} - 59.5^{KF} = 0$$

The fact that $M_R$ returns to zero (0) checks the arithmetic by verifying the static equilibrium equation, $\Sigma M = 0$.

(7) For a uniformly distributed load, such as dead load, the shear and moment diagrams will always be of the same general shape. The shear diagram is a sloping line crossing the X-axis at midspan and the moment diagram is a parabola. The only variations will be in magnitude. With the same 40-foot beam as in figure 2–45(a), the point loads are replaced with a distributed load of w = 1 k/ft. in figure 2–46. The reaction, calculated from the formulas of figure 2–43 (a) are:




$$R_L = R_R = \frac{w.L}{2} = 1\frac{k}{ft}\frac{(40')}{2} = 20^{k}$$

$$V_L = R_L = 20^{k}$$
$$V_X = R_L - wx$$
$$V_{a_1} = 20^{K} - 1\tfrac{K}{ft}(18.6') = 1.4^{K}$$
$$V_{℄} = 20^{K} - 1\tfrac{K}{ft}(20') = 0$$
$$V_{a_2} = 20^{K} - 1\tfrac{K}{ft}(32.6') = -12.6^{K}$$
$$V_R = 20^{K} - 1\tfrac{K}{ft}(40') = -20^{K}$$
$$V_R + R_R = -20^{K} + 20^{k} = 0$$

$$M_{a_1} = m + n = 1.4^{k}(18.6') + (20 - 1.4)^{k}(18.6')\tfrac{1}{2}$$
$$M_{a_1} = 26 + 173 = 199^{kf}$$
$$M_{℄} = m + n + p = 199^{kf} + 1.4^{k}(1.4')\tfrac{1}{2}$$
$$M_{℄} = 199^{kf} + 1.0^{kf} = 200^{kf}$$
$$M_{a_2} = M_{℄} - q = 200 - 12.6^{k}(12.6')\tfrac{1}{2}$$
$$M_{a_2} = 200^{kf} - 79.4^{kf} = 120.6^{kf}$$
$$M_R = M_{a_2} - r - s$$
$$M_R = 120.6^{kf} - 12.6^{k}(7.4') - 7.4^{k}(7.4')\tfrac{1}{2}$$
$$M_R = 120.6^{kf} - 93.2^{kf} - 27.4^{kf} = 0$$

*Figure 2–46. Shear and moment diagrams for uniform loads.*

$$R_L = R_R = \frac{wL}{2} = \frac{1\text{ k/ft.}}{2}(40') = 20^K$$

The end shear is again equal to the left reaction, $V_L = R_L = 20^K$. The shear at any point on the beam may be calculated by the formula shown in figures 2–43(b) and 2–43(c), i.e.,

$$V_X = \frac{wL}{2} - wX \text{ or } R_L - wX.$$

Figuring the shear for the same points $X = a_1$ and $X = a_2$, as well as at midspan, the shears are as shown in figure 2–46(b).

$$V_{a_1} = 1.4^K,\ V_{℄} = 0,\ V_{a_2} = -12.6^K$$

At the right support, $V_R = 20^K - \frac{1k\ (40')}{ft.} = -20^K$ which is again equal and opposite to $R_R$. The moment curve is figured either by applying the formula $M_X = \frac{1}{2}wx(L-x)$ given on figure 2–43(c), or by adding the areas under the shear diagram. (The latter will be done in this illustration). $M_L = 0$, of course, and $M_{a_1}$ is obtained by calculating the trapezoidal area between $X = 0$ and $X = a_1 = 18.6'$. The trapezoidal area is divided into rectangle "n" and a triangle "m" as shown in Figure 2–46(b).

$$M_{a_1} = 1.4^K(18.6') + (18.6^K)(18.6')(\tfrac{1}{2}) = 199^{KF}$$

At midspan where $X = 20'$, the moment is the moment at $X = a_1$ plus the area of the small triangle "p" between $X = a_1$ and midspan.

$$M = 199^{KF} + 1.4^K(1.4')1/2 = 199^{KF} + 0.98^{KF} = 200^{KF}$$

At $X = a_2$, the moment is reduced by the area of the triangle "q" between midspan and $X = a_2$; or

$$M_{a_2} = 200^{KF} - 12.6^K(12.6')1/2$$
$$= 200^{KF} - 79.4^{KF} = 120.6^{KF}$$

Finally the area of the trapezoid ("r" + "s") between $X = a_2$ and the right support is added to $M_{a_2}$ and

$$M_R = 120.6^{KF} - (12.6^K)7.4' - \frac{(7.4^K)(7.4')}{2}$$

$$M_R = 120.6^{KF} - 93.2^{KF} - 27.4^{KF} = 0$$

as it should be.

(8) In figure 2–47, the distributed load and concentrated loads are combined. The figures may be obtained by superposition or simply adding the reactions, shears, and moments at the corresponding section. While the shear and moments can be obtained from the combined loads directly, it is suggested that the loads be treated separately until some proficiency in this type of calculations has been acquired. Attention is called to the fact that maximum shear occurs at the supports and that maximum moment occurs at the section where the vertical shear diagram passes thru zero. The set of sample calculations presented in figures 2–45 and 2–46 is intended to give a unified demonstration of the procedure. It should be noted that non-uniform distributed loads are often encountered in actual practice, and that the live loads represented by the concentrated loads can change position. For the H truck, the position used in figure 2–45 produces maximum moment, but not maximum shear. A different truck will produce maximum moments at another location on the beam.

f. There is no doubt that many questions have been left unanswered by this brief exposition. Such topics as torsion, negative moment, and moving loads have not been discussed. It is expected that the instructor will amplify the foregoing discussion to the extent that the needs and the interest of the trainees dictate.

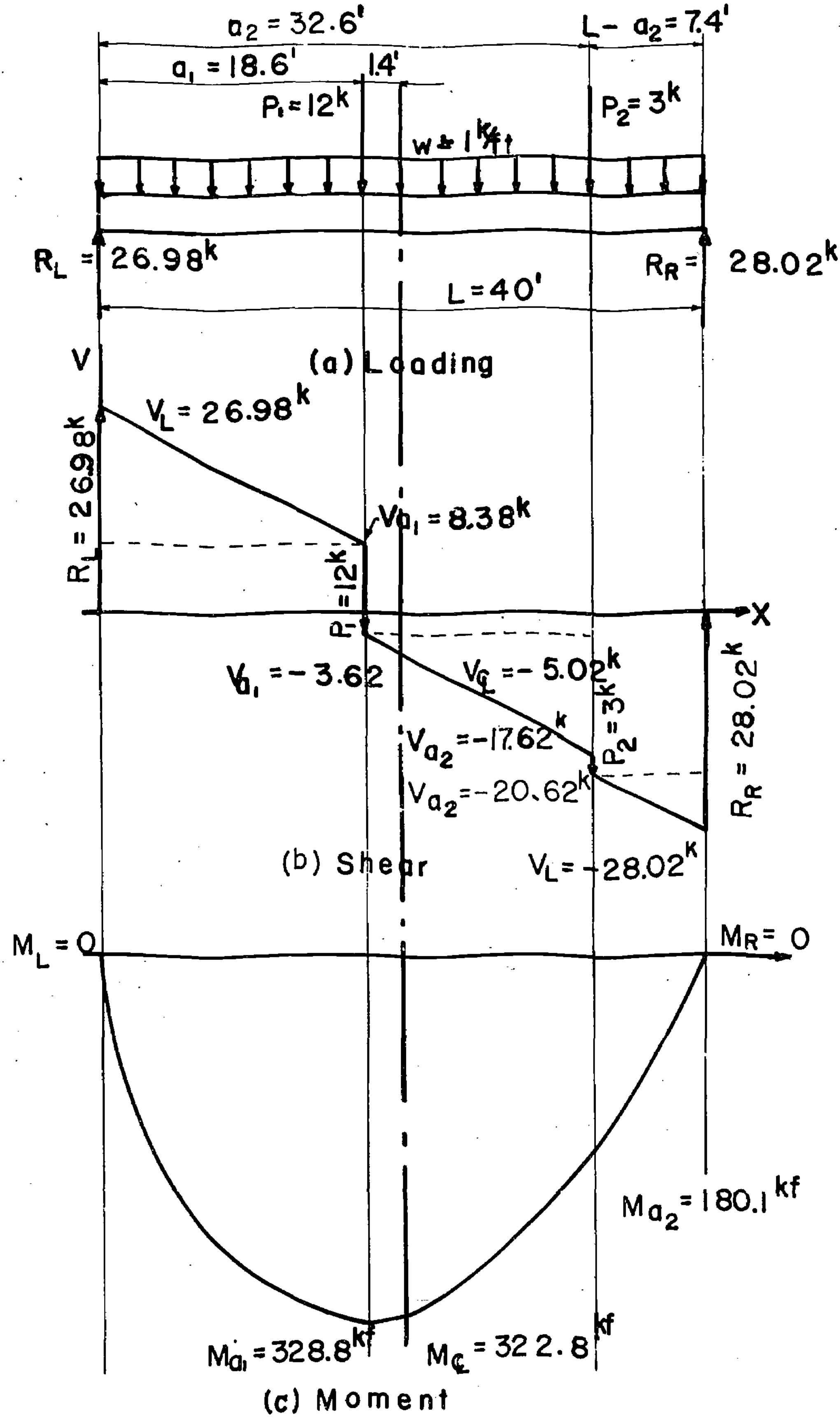



*Figure 2–47. Shear and moment diagrams for both concentrated and uniform loads.*

# CHAPTER III

# BRIDGE INSPECTION REPORTING SYSTEM

## *Section 1. INTRODUCTION*

### 3–1.1 General.

A good bridge inspection reporting system is essential in order to protect the lives of the public and to protect the public's investment in bridge structures. It is, therefore, essential that bridge inspection reports be clear and complete, since they are an integral part of the lifelong record file of the bridge. While a number of states have for years had a reporting system for bridge inspections, the reporting systems have been almost unique to each individual state. Moreover, information contained in many reports has unfortunately not always been sufficient nor has it been in a form suitable for analysis and evaluation from both a qualitative and quantitative standpoint. In a number of states, the bridge reporting system must be formulated and designed so that report information can be analyzed and evaluated, to a large extent, by electronic data processing means. This requirement is because of the large number of bridge structures located within those states. Because of the requirements that must be fulfilled by the National Bridge Inspection Standards, it is necessary to employ a uniform bridge inspection reporting system. A uniform reporting system is essential in evaluating correctly and efficiently the condition of all structures. Furthermore, it will be a valuable aid in determining maintenance priorities, replacement priorities, structure capacity, and the cost of maintaining the nation's bridges. The information necessary to make these determinations must come largely from the bridge inspection reporting system. Consequently, the importance of the reporting system cannot be over emphasized. The success of any bridge inspection program is dependent upon its reporting system.

### 3–1.2. Purpose.

The purpose of the bridge inspection reporting system is to have trained and experienced personnel record objective and subjective observations of all elements of a bridge structure and to make logical deductions and conclusions from their observations. The bridge inspection report should represent a systematic inventory of the current condition of all bridge members and their possible future weaknesses. Moreover, bridge reports form the basis for quantifying the manpower, equipment, materials, and funds that are necessary to maintain the integrity of the structure.

### 3–1.3 Requirements.

The requirements of a good field reporting system are:

a. A thorough study of all available historical information on the structure including design and/or "as built" plans, field and design changes, foundation information, records of previous inspections, and any other available information relative to the structure.

b. Information on repairs performed and reconstruction work completed on the structure.

c. Current bridge inventory information.

d. A procedure for making the inspection of a structure.

e. An inspection recording system.

(1) A notebook format.

(2) Standard forms.

(3) Notebook and standard forms.

f. A standard notation system for indicating the condition of the various elements or members.

g. Sketches and drawings of members and components that are to be inspected.

h. A standard nomenclature for bridge elements and members and the components made up of these members.

i. A summary sheet.

(1) Qualitative condition of the structure in general.

(2) A quantitative summary.

(a) Work needed by priority and its cost.

(b) Total cost of all repairs.

j. A provision for specialist reports such as structural, mechanical, and electrical.

k. A narrative summary section for short, concise narrative reports of the condition of the structure.

l. A section for special repair procedures that might be recommended by the inspector.

m. A section in which the inspector gives special instructions for the repair or for further inspection of a structure.

The above items are considered to be minimal requirements in the establishment of a bridge reporting system which will assure completeness, uniformity, and continuity of inspection over the years. As advancements are made and structures change, there will necessarily be refinements, but this basic content outline should provide for the development of a system that can be profitably used by all states for many years to come.

## Section 2. PREPARATION FOR INSPECTION

### 3–2.1 Inspection Types.

a. *Routine Inspections.* Routine inspections shall be made on all structures at least once every two years.

b. *Interim Inspections.*

(1) *Weight-Limited Structures.* Inspections shall be made at least once a year on all structures not capable of carrying the state's legal load limit.

(2) *Structurally Deficient Bridges.* Structurally deficient bridges shall be inspected as often as required to assure the safety of the public and the integrity of the structure.

(3) *Special Inspections.* Special inspections may be required for many reasons, some of which are:

(a) Structures damaged by accidents or other causes.

(b) Inspections for gathering information for possible reconstruction or replacement.

(c) Inspections for routing overweight vehicles.

### 3–2.2 Scheduling.

A schedule should be developed for all types of inspections. The schedule should be followed as closely as possible to assure that all structures will be inspected within the required time span. Scheduling of any bridge inspection should be accomplished sufficiently far in advance to permit the coordination of manpower, equipment, and specialist personnel. Sufficient time and manpower should be allocated for the special inspections that may be required.

### 3–2.3 Planning and Reporting the Inspection.

a. *General.* Careful planning of the inspection and selection of appropriate reporting formats are essential for a well-organized, complete, and efficient inspection. During the planning phase the following items should be considered:

(1) The inspection schedule.

(2) The inspection type.

(3) The resources required: Manpower, equipment, materials, and special instruments.

(4) A study of all pertinent available information on the structure such as plans, previous inspections, current inventory report, and previous repairs.

(5) The type of reporting system to be used: notebooks, standard forms, or both.

(6) Setting up the notebooks, including the notation system and all of the required preliminary drawings and sketches.

(7) Coordinating the resource requirements, particularly that of specialist personnel and special equipment.

(8) The inspection procedure.

b. *Scheduling.* An inspection schedule is necessary to assure that all structures are inspected when programmed. Detailed scheduling is essential to assure that the proper manpower and equipment are available when they are needed. At times, the weather, stream levels and seasonal traffic loads of the structure must be taken into consideration in scheduling the inspection.

c. *Inspection Type.*

(1) *Routine Inspection.* Routine inspections will follow the procedures described in the National Bridge Inspection Standards and those set forth in this training manual.

(2) *Interim Inspection.*

(a) *Weight-Limited Structures.* Sufficient data must be gathered to determine what the limiting members of the structure are and what weight limit should be prescribed. If possible, the date for any reinspection should be determined. Changes in the character of the bridge traffic should be noted and recommendations concerning repairs needed to maintain the structure at its present rating should be made.

(b) *Structurally Deficient Bridges.* Inspections should be performed as often as is required to ensure the safety of the public and the structure. The type and extent of the deficiencies of each member should be recorded in sufficient detail to permit the determination of the safe carrying capacity of the structure. Recommendations for repairs necessary to maintain the structure in a usable condition should be submitted.

(c) *Special Inspection.* Sufficient data must be gathered to satisfy the specific purpose of the inspection. For instance, a damaged structure should be closely examined both in the damaged area and in adjacent areas to determine the extent of structural deterioration.

d. *Resources Required.* While all needed manpower, equipment, materials, and instruments should normally be available to the inspection organization itself, special resources may sometimes be required. Mechanical, electrical, hydraulics, or underwater inspection specialists will be needed for some inspections. Special instruments such as ultrasonic measuring devices, electronic depth finders, and others may be required. Special equipment such as additional scaffolding, "cherry pickers," and "snoopers" may have to be obtained.

e. *Data Study.*

(1) *The Plan Review.* The review should be made using "as built" plans. If the "as built" plans are not available, design plans may be used. The review of the structure's plans should include a study of such environmental features as the stream's channel, the flood plane, utilities on the right-of-way, the right-of-way itself, soil and foundation information, stream profile and stream protection devices, and stream elevations at normal and high water levels. If the stream is navigable, note what navigation devices are employed. Special attention should be paid to unusual or complex features of the structure. Plans should be studied in detail to note possible critical areas of the structure. Previous experience should be resorted to as a means for identifying those areas that frequently cause problems. After a thorough review of the plans, the type of reporting format can be determined.

(2) *Data Review.* A study should be made of the most recent inventory report, the newest traffic data, previous inspections, repairs and reconstruction work, and any other available historical data related to the structure.

(3) *Procedure Plan.* In most instances, it is advantageous to inspect structures in the same sequence in which they are constructed. That is, the substructure foundations first, and the superstructure next. Chapter IV includes a more detailed discussion of the inspection sequence.

f. *Reporting Format.*

(1) *Notebook.* The notebook will normally be used as the sole reporting format on structures that are complex or unique. See Section 3–3.

(2) *Standard Forms.* Forms should be sufficiently flexible so as to be adaptable to most structures. See Section 3–5.

(3) *Notebook and Standard Forms.* It is sometimes advantageous to use a notebook for the unique to complex portions of the structure, and standard forms for the more common parts.

## Section 3. PREPARING THE INSPECTION NOTEBOOK

### 3–3.1 General.

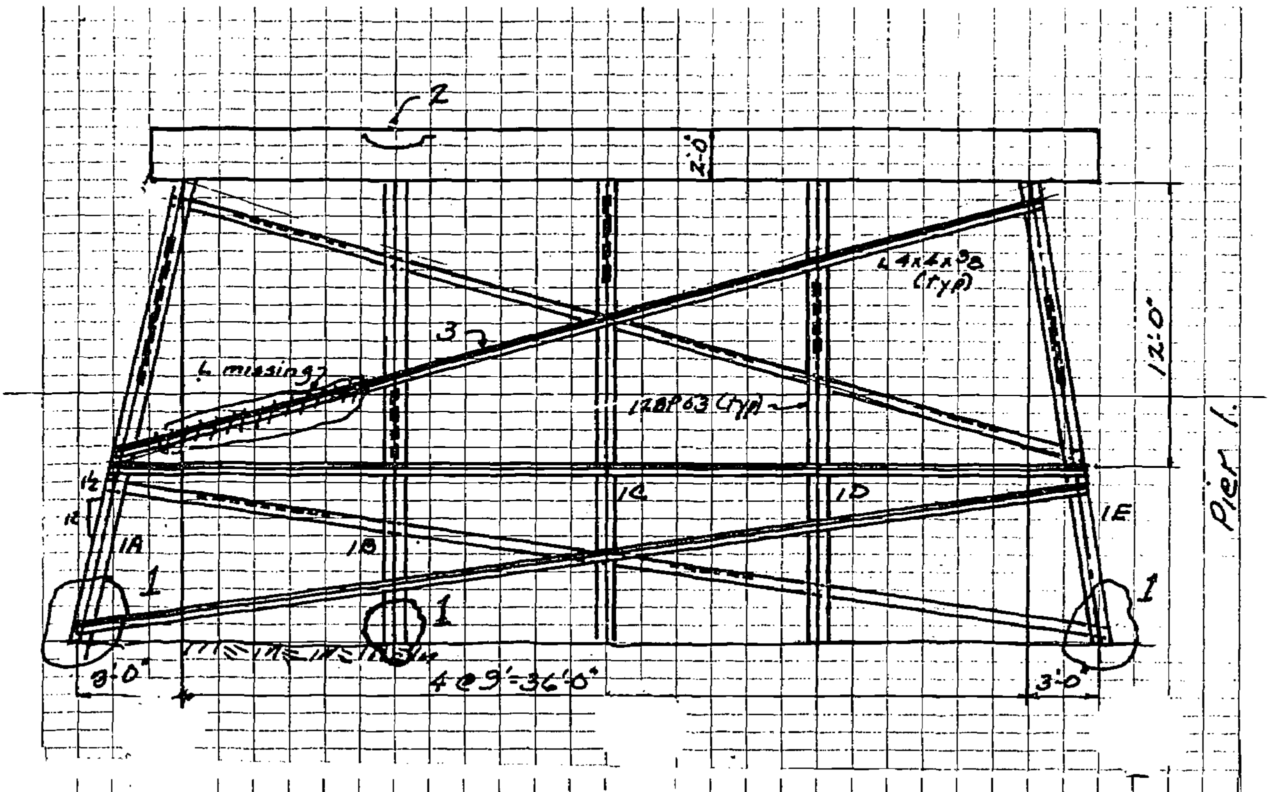
When the notebook format is selected for recording bridge inspection results, the information should be recorded systematically. The following describes a suggested content outline.

a. *Title Page.* The title page should contain the name of the structure, the structure identification number, the road section identification number, and the name of the crossing. The back of the title page should be used to note the names of the members of the inspection party, the person in charge of the party, the type of inspection, and the dates on which the inspection was made.

b. *General Format.* The left-hand page should contain the name of the member being inspected, its components, the evaluation of that member and its components, and appropriate associative space for comments. The right-hand page should be reserved for sketches or drawings of the member. The notebook should be arranged sectionally in the order in which the structure was built, i.e., starting with the substructure and ending with the superstructure. The format of each section of the notebook should be arranged so as to proceed from the general to the specific, i.e., from a general layout of a particular unit to the details of that unit. This applies to evaluations and to sketches as well. Figure 3–1 illustrates the dividing of a bridge into three main parts, and the further division of these parts. Figures 3–2 through 3–6 show the details of some of these units.

| 10. | Bridge 94-93-3 | |
|---|---|---|
| | Substructure | |
| No. Abutment | | p. 11 |
| Pier 1 | | 12 |
| Pier 2 | | 13 |
| Pier 3 | | 16 |
| Pier 4 | | 19 |
| So. Abutment | | 20 |
| | Superstructure | |
| Span 1 | | 21 |
| Span 2 | | 22 |
| Span 3 | | 25 |
| Span 4 | | 28 |
| Span 5 | | 31 |
| | Deck | |
| Span 1 | | 32 |
| Span 2 | | 33 |
| Span 3 | | 34 |
| Span 4 | | 35 |
| Span 5 | | 36 |
| | | 37 |

*Figure 3–1. Typical notebook index page. Division of a typical bridge into its main parts.*




12 Bridge 94-93-3

Pier 1 (Pile Bent)

| Element No. | Ele. Name | Rating | Problem | Comment |
|---|---|---|---|---|
| 1 | Steel H-Pile | 6 | Corrosion Piles A&B &E | @ mud line |
| 2 | R/C Cap | 7 | Cracked | due to expansion of T-bm |
| 3 | Sway Brcg | 7 | Badly rusted | needs replacing |

*Figure 3–2. Typical notebook page. Note drawing on right-hand page, and evaluation of circled elements on left-hand page.*

### 3–3.2 Sketches.

In most cases it will be possible to insert reproductions of portions of the plans in the notebook. However, in some instances sketches will have to be drawn.

a. *Overall Sketch.* The first sketch should schematically portray the general layout of the bridge, illustrating the structure plan and elevation data. The immediate area, the stream or terrain obstacle layout, major utilities, and any other pertinent details should also be included.

b. *Substructures.* Sketches or drawings of each substructure unit should be included. In many cases it will be sufficient to draw typical units which identify the principal elements of the substructure. Each of the elements of a substructure unit should be numbered so that they can be cross referenced to the information ap-

16 Bridge 94-93-3

Pier 3 (Solid R/C)

| Element No. | Ele. Name | Rating | Problem | Comment |
|---|---|---|---|---|
| 1 | Dolphin | 7 | Insect Attack | Replace |
| 2 | Fenders So. Face | 7 | Collision Damage | Replace |
| 3 | Pier Stem | 8 | | |
| 4 | Scour Protect'n | 7 | Scour Developing | See soundings on p.17 |

*Figure 3–3. Typical notebook page. This is a left-hand page showing the evaluation of pier elements.*

pearing on the data page on the left-hand side of the sketch. Items to be numbered include piling, footings, vertical supports, lateral bracing of members and caps.

c. *Superstructures.* Superstructure units should be sketched both in cross section and plan and elevation views. The elements of the superstructure units should be numbered as they were in the substructure units. Items to be numbered include bearings, main supporting members, floor beams, stringers, bracing, diaphragms, windbracing, decks, expansion joints, curbs, and hand rails.

d. *Special Sketches.* Additional sketches may have to be prepared of critical areas of certain bridges.

(1) *Trusses.* Critical areas of trusses include connections from floor beams to chords, gusset plates at panel points, portals, cross

| 21 | Bridge 94-93-3 | | | |
|---|---|---|---|---|
| | Span 1 - R/C T-bm | | | |
| Element No. | Ele. Name | Rating | Problem | Comment |
| 1A & 1E | T-bms. (fascia) | 6 | Scaling & Spalling under scuppers | Rebars exposed Gunite? |
| 2 | Scuppers | 7 | Poor Scupper Design | Add longer pipes |
| 3 | End Diaphragm | 7 | Severe Scale | Poor deck drainage |

*Figure 3-4. Typical notebook page. This is a left-hand page showing the evaluation of span elements.*

frames, damaged members, bearings, eyebars, and heavily corroded areas.

(2) *Suspension Bridges.* Sketches of suspension bridges should include, but not necessarily be limited to, anchorages, towers, cable bents, tower saddles, cable bands, suspender saddles, suspender connections, and stiffening truss connections. The critical areas on the stiffening trusses are the same as those listed under "Trusses" in the previous paragraph. It is particularly important to detail rocker bearings for towers and cable bents when they exist, the main cable cross section, heavily corroded members, cable bands, and cable wrappings.

(3) *Swing Spans.* Critical areas include truss details and connections, machinery, locks, electrical systems, controls, and girder details for girder type swing spans.

(4) *Bascule Spans.* The required details include counterweights, trunnion details, locks, machinery, buffers, cables, controls, corroded members, and details of connections of trusses and girders.

(5) *Vertical Lift Spans.* Critical areas include cables, anchorages for the cables, trunnions, sheaves, guides, limit switches, counterweights, counterweight balance chains, buffers, locks, machinery, electrical system, controls, corroded members, and bearings.

(6) *Cantilever Bridges.* On cantilever bridges, sketches are generally required for the hinges for the suspended span, rockers, bearings, the hold-down devices, if any, in the anchor spans, truss or girder details, and the corroded areas.

(7) *Bearing Devices.* Since bearing devices are a frequent source of trouble they should be inspected with particular care. Sketches should be made of each major bearing device showing its position, as in figure 3–6. Sketches should be made of any bearing that is not functioning properly.

(8) *Miscellaneous Sketches.* Sketches of fenders, dolphins, and aerial and navigational lighting will sometimes be required. Special terrain features or unusual slope protection or channel protection conditions will require sketches. Sketches may also be required for expansion devices.

(9) *Additional Sketches.* Since additional sketches may be required, it is a good practice to leave blank every third or fourth page for this purpose.

e. *Alignment.* A section of the notebook should be reserved for recording the horizontal and vertical alignment of the structure. Alignment should be checked for structures that are long, or show evidence of misalignment.

(1) *Substructure Drawings.* Drawings of each substructure unit should include a side elevation view and the two end elevation views. These sketches should be large enough so that the structure's horizontal and vertical alignment can be noted on the sketches after they have been determined.

(2) *Superstructure.* Sketches showing the plan and elevation views of the superstructure are necessary. The horizontal alignment should be noted on the plan view of the structure, and the vertical alignment of the elevation view.

f. *Environmental Features.* The environmental features that should be included are terrain features, stream profiles, high water elevation, spur dikes or other protection devices, slope protection, channel protection, and the channel location where it passes under the structure. In some instances it is desirable to show the channel condition upstream and downstream from the structure. The horizontal and vertical alignment of the approach roadway should also be shown.

g. *Underwater Investigation.* Plots of the contour of the stream bottom should extend to a radius of at least 100 feet from each pier. The purpose of the contour plots is to determine the extent of the scour. On the contour drawings, a plan view of the foundation should be included.

h. *Specialist Reports.* The final section of the notebook should include the reports of mechanical, electrical, or other specialists.

## *Section 4. STRUCTURE EVALUATION*

### 3–4.1 General.

A bridge is typically divided into two main units—the substructure, and the superstructure. For convenience the deck is sometimes considered as a separate unit. These basic units may be divided into structural members, which, in turn, may be further subdivided into ele-

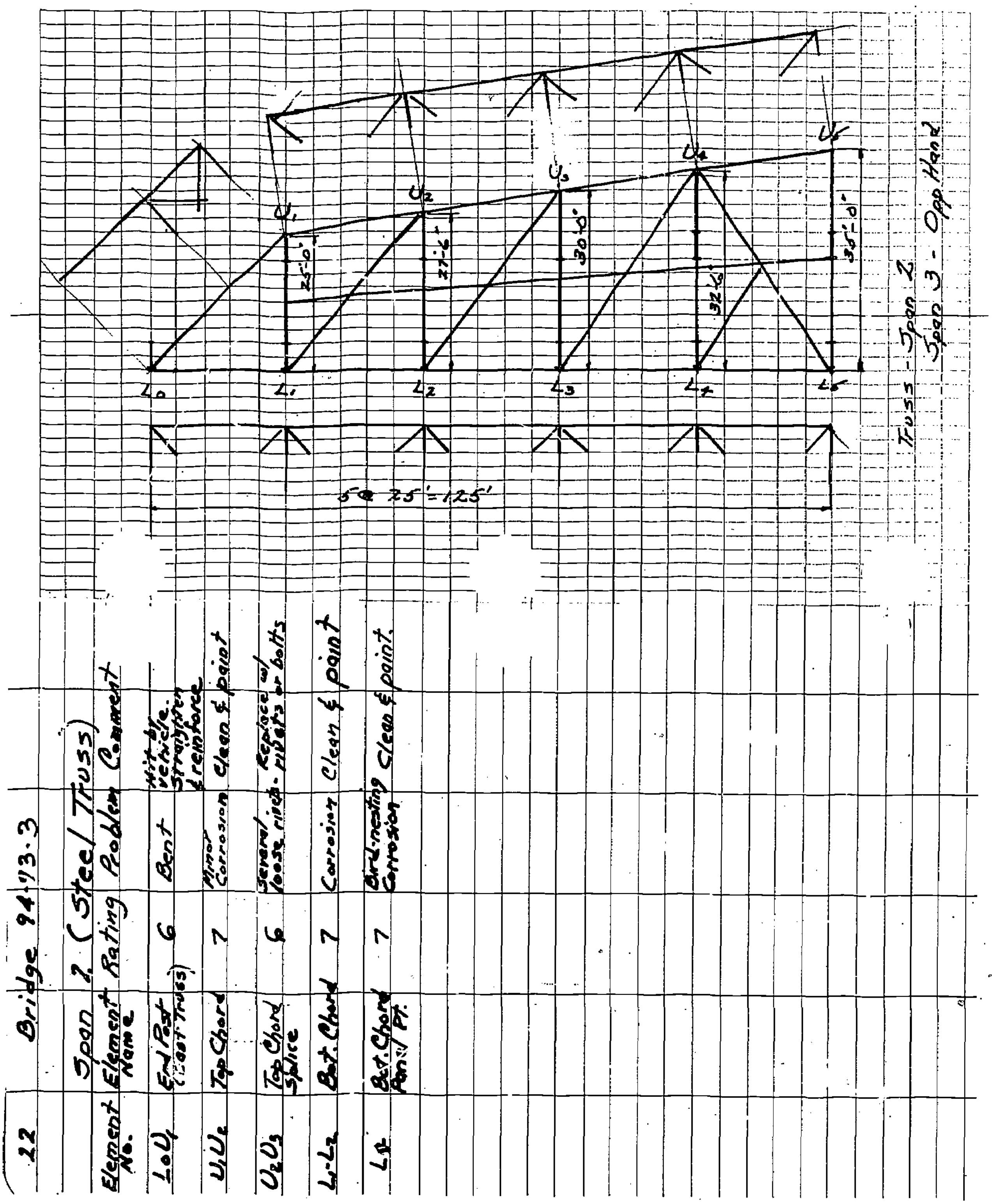



*Figure 3–5. Typical notebook page. Members are coded by letter and number to permit easy identification.*

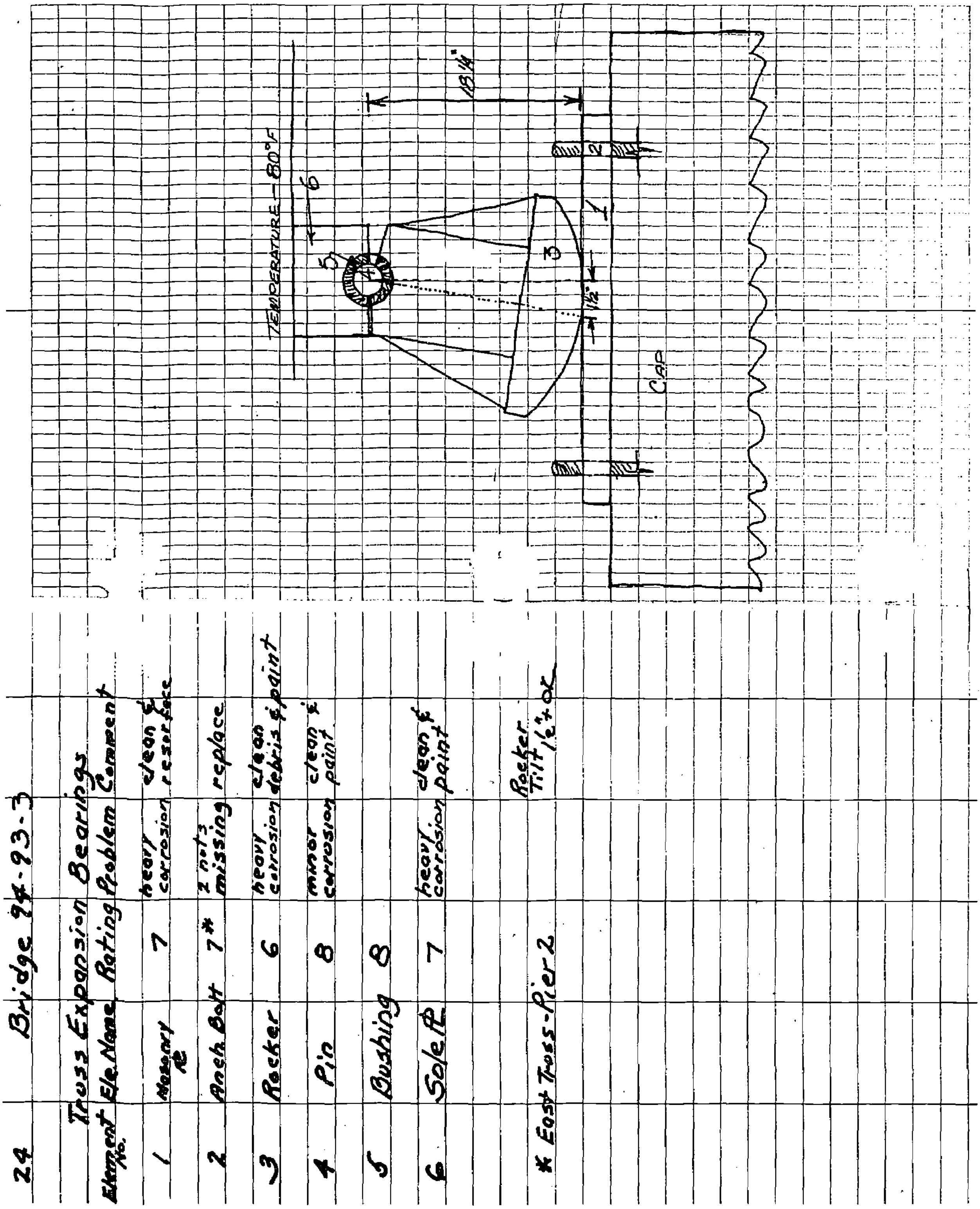



*Figure 3–6. Typical notebook page. Elements of bearings are identified and rated. Note that location of bearing is also included.*

ments or components. The general procedure for evaluating a structure is to assign a numerical rating to the condition of each element or component of the main units. These ratings may be combined to obtain a numerical value for the overall condition of a member or of a unit.

### 3–4.2 Numerical Evaluation.

Numerical ratings of bridge components are useful for the evaluation of the bridge. It is not mandatory for the bridge inspector to make numerical ratings unless so instructed. However, if he desires to assign numerical ratings, he should follow the rating system explained below. Note that ratings "0," "1," "2," "3," "4," and "6" apply only to major components and elements. The recommended rating system is as follows:

a. "9"—new condition.

b. "8"—good condition—no repairs necessary.

c. "7"—minor items in need of repairs by maintenance forces.

d. "6"—major items in need of repairs by maintenance forces.

e. "5"—major repairs contract needs to be let.

f. "4"—minimum adequacy to tolerate present traffic—immediate rehabilitation necessary to keep open.

g. "3"—inadequacy to tolerate present heavy load—warrants closing bridge to trucks.

h. "2"—inadequacy to tolerate any live load —warrants closing bridge to all traffic.

i. "1"—bridge repairable, if desirable to reopen to traffic.

j. "0"—bridge conditions beyond repair—danger of immediate collapse.

### 3–4.3 Explanatory Aids.

a. *Narrative Descriptions.* Descriptions of the condition should be as clear and concise as possible. Completeness, however, is essential. Therefore, narrative reports of moderate length will sometimes be required to adequately report on bridge conditions.

b. *Photographs.* Photographs will be of great assistance to anyone who is reviewing reports on bridge structures. It is particularly recommended that pictures be taken of any problem areas that cannot be completely explained by a narrative description. It is better to take several photographs that may be unessential than to omit one that would preclude misinterpretation or misunderstanding of the report. At least two photographs of very structure should be taken. One of these should depict the structure from the roadway while the other photo should be a view of the side elevation.

c. *Summary.* An inspection is not complete until a narrative summary of the condition of the structure has been written.

d. *Recommendations.* The inspector should list according to urgency any repairs that are necessary to maintain structural integrity and public safety. Recommendations are discussed in greater detail in Chapter VI.

## *Section 5. STANDARD FORMS*

### 3–5.1 General.

On large or complex bridges, the notebook format must be used to record inspection results. However, for small and simple bridges, it may be more convenient to use standard forms (figs. 3–7(a), 3–7(b), and 3–7(c); the forms shown represent an amplification of the condition rating section contained in the Structure Inventory & Appraisal Sheet from the A.A.S.H.O. "Manual for Maintenance Inspection of Bridges"). When using standard forms, the evaluation numbers and comments may be recorded exactly as described in Section 3–4 for notebooks. The reverse side of the forms can be used for drawing sketches and for additional comments.

If available, standard prepared sketches should be attached to the forms with the coding of all members clearly indicated. Where sketches and narrative descriptions cannot fully describe the deficiency or defect, photographs should be taken and should be referenced appropriately in the narrative. All items on the forms shown in figures 3–7(a), 3–7(b), and 3–7(c) may not always be filled out. Prior to the inspection, it should be determined which items

BRIDGE INSPECTION REPORT

Bridge No.__________ Bridge Type____________________________ Inspector__________

Name____________________ Crossing Over/Under____________________________ Date________

Year Built_____ District__________________ County____________________ Photographs________

Field Book No.__________

CONDITION RATING — REMARKS

## 58 DECK

1. Wearing Surface
2. Deck - Structural Condition
3. Curbs
4. Median
5. Sidewalks
6. Parapet
7. Railing
8. Paint
9. Drains
10. Lighting Standards
11. Utilities
12. Joint Leakage
13. Expansion Joints or Devices
14. Record Elevations
    Gutterline @ ℄ Brgs
    @ ℄ Spans

Inspectors Condition Rating

## 59 SUPERSTRUCTURE

1. Bearing Devices
2. Stringers
3. Girder or Beams
4. Floor Beams
5. Trusses - General
   - Portals
   - Bracing
6. Paint
7. Machinery (Movable Spans)
8. Rivets or Bolts
9. Welds - Cracks
10. Rust
11. Timber Decay
12. Concrete Cracking
13. Collision Damage
14. Deflection under load
15. Alignment of Members
16. Vibrations under load

Inspectors Condition Rating

*Figure 3-7(a) First page of a typical bridge inspection form.*

Bridge No. ______ (continued)

| | CONDITION RATING | REMARKS |
|---|---|---|
| **60** SUBSTRUCTURE | | |
| 1. Abutments - Wings | | |
| - Backwall | | |
| - Footing | | |
| - Piles | | |
| - Erosion | | |
| - Settlement | | |
| 2. Piers or Bents - Caps | | |
| - Column | | |
| - Footing | | |
| - Piles | | |
| - Scour | | |
| - Settlement | | |
| 3. Pile Bents | | |
| 4. Concrete Cracking or Spalling | | |
| 5. Steel Corrosion | | |
| 6. Timber Decay, etc. | | |
| 7. Debris on Seats | | |
| 8. Paint | | |
| 9. Collision Damage | | |
| Inspectors Condition Rating | | |
| **61** CHANNEL & CHANNEL PROTECTION | | |
| 1. Channel Scour | | |
| 2. Embankment Erosion | | |
| 3. Drift | | |
| 4. Vegetation | | |
| 5. Channel Change | | |
| 6. Fender System | | |
| 7. Spur Dikes & Jetties | | |
| 8. Rip Rap | | |
| 9. Adequacy of Opening | | |
| Inspectors Condition Rating | | |
| **62** CULVERT & RETAINING WALLS | | |
| 1. Barrel | | |
| Concrete | | |
| Steel | | |
| Timber | | |
| 2. Headwall | | |
| 3. Cutoff Wall | | |
| 4. Adequacy | | |
| 5. Debris | | |
| Inspectors Condition Rating | | |

*Figure 3–7(b). Second page of a typical bridge inspection form.*

are not applicable for the bridge to be inspected. The inspector is encouraged, but not required, to make numerical evaluation ratings of the various bridge elements on the forms. Nevertheless, he is required to describe their condition.

Bridge No.________(continued)

| | CONDITION RATING | REMARKS |
|---|---|---|
| **63** ESTIMATED REMAINING LIFE | | |
| Inspectors appraisal of structural condition of structure | | ☐ |
| **64** OPERATING RATING | | |
| **65** APPROACH ROADWAY | | |
| 1. Alignment | ☐ | |
| 2. Approach Slab | ☐ | |
| 3. Relief Joints | ☐ | |
| 4. Approach-Guardrail | ☐ | |
| -Pavement | ☐ | |
| -Embankment | ☐ | |
| 5. Signing - Legibility and Visibility | ☐ | |
| 6. Record posted load limits if any. | | |
| Inspectors Condition Rating | ☐ | |
| **66** INVENTORY RATING | | |

*Figure 3–7(c). Third page of a typical bridge inspection form.*

# CHAPTER IV

# INSPECTION PROCEDURES

## Section 1. SEQUENCE OF INSPECTION

### 4–1.1 General.

The development of a sequence for the inspection of a bridge is important since it actually outlines the plan for inspection. A well constructed sequence will provide a working guide for the inspector and insure a systematic and thorough inspection.

a. *Factors.* Some of the factors that influence the procedure or sequence of a bridge inspection are:

(1) Size of the bridge

(2) Complexity of the bridge

(3) Traffic density

(4) Availability of specialists

(5) Availability of special equipment.

(6) Preferences of the inspecting agency

b. *Thoroughness of Inspection.* Thoroughness is as important as the sequence of inspection. Particular attention should be given to:

(1) Structurally important members

(2) Members most susceptible to deterioration or damage

c. *Visual Inspection.* Dirt and debris must be removed to permit visual observation and precise measurement. Careful visual inspection should be supplemented by appropriate special devices and techniques. Use of closed circuit television, photography, and mirrors will increase visual access to many bridge components.

### 4–1.2 Inspection Sequence.

a. *Average Bridges.* For bridges of average length and complexity, it is convenient to conduct the inspection in the following sequence:

(1) *Substructure units*

(a) Piles

(b) Fenders

(c) Scour protection

(d) Piers

(e) Abutments

(f) Skewbacks

(g) Anchorages

(h) Footings

(2) *Superstructure units*

(a) Main supporting members

(b) Bearings

(c) Secondary members and bracing

(d) Utilities

(e) Deck—including roadway and joints

(f) End dams

(g) Sidewalks and railings

(3) *Miscellaneous*

(a) Approaches

(b) Lighting

(c) Signing

(d) Electrical

(e) Barriers, gates, and other traffic control devices

b. *Large Bridges.* While the sequence of inspection for large bridges will generally be the same as for smaller bridges, exceptions may occur in the following situations:

(1) *Hazards.* Climbing and other hazardous tasks should be accomplished while the inspector is fully alert.

(2) *Weather.* Wind, extreme temperatures, rain, or snow may force the postponement of hazardous activities such as climbing, diving, or water-borne operations.

(3) *Traffic.* Median barriers, decks, deck joints, traffic control devices, and approaches should be inspected in daylight during periods of relatively light traffic to ensure inspector safety and to avoid the disruption of traffic.

(4) *Inspection Party Size.* When the inspection party is large, several different tasks may be performed simultaneously by different inspectors or groups of inspectors.

## Section 2. SYSTEMATIC INSPECTION PROCEDURES

### 4–2.1 General.

Inspection of each part of the structure should be planned and outlined in detail to avoid oversights. Inspection results should provide comprehensive records of bridge deterioration over a period of time. Such records are a source of reference for future analyses and study purposes. Check list techniques should be employed to preclude the possibility of any bridge component being overlooked during the course of inspection. For example, panel points or control points labeled for inspection in the field book, should also be marked with paint or crayon on the corresponding points of the structure during inspection. This is especially important on large and complex structures. Once the sequence of inspection of a bridge has been established, it then becomes necessary to identify those items that must be inspected. The material that follows discusses the principal elements of such a process.

### 4–2.2 Substructure.

a. *Piers, Abutments, and Bents.* All piers, abutments, and bents should be surveyed with respect to both horizontal and vertical dimensions and the data compared with the "as built" plans, if available.

b. *Scour and Slope Protection.* Make guide marks with keel or paint on the pier cap, pier face, or abutment face, as the case may be. (The location of these marks should be noted carefully in a sketch on the inspection form or in the field book.)

Move away from the mark on a pier along a radial or perpendicular and take soundings at fixed intervals, e.g., 20 feet or 25 feet, up to a minimum radius of 100 feet. Repeating this procedure at each mark will result in a grid-like pattern of soundings of river bottom elevations (fig. 4–1). For very long piers, or those where serious scour is detected, additional measurements may be made at intermediate points by adding more radial and tangential lines to the pattern. The reference marks on the pier should be carefully defined so that they can be found or reestablished in subsequent inspections. This will permit compilation of a good, long-term record or scour development and slope protection deterioration. Soundings may be made from a boat with a rod, a weighted line, or electronic equipment. Each of these methods has its limitations:

(1) A rod is useful for shallow depths only.

(2) A weighted line is difficult to use in a swift current.

(3) Electronic equipment is unreliable where the bottom is shallow, rocky, irregular, or close to the pier.

c. *Framed Bent or Pile Bent Piers.* List each pier and identify each column or pile by a number or letter.

d. *Bearings.* After the inspection of piers, the bearings of the superstructure may be inspected, if convenient.

e. *Cracks and Spalls.* Note location, size, and extent of cracks, spalls, scaling, and joint movements of substructure members, as discussed in Chapter V.

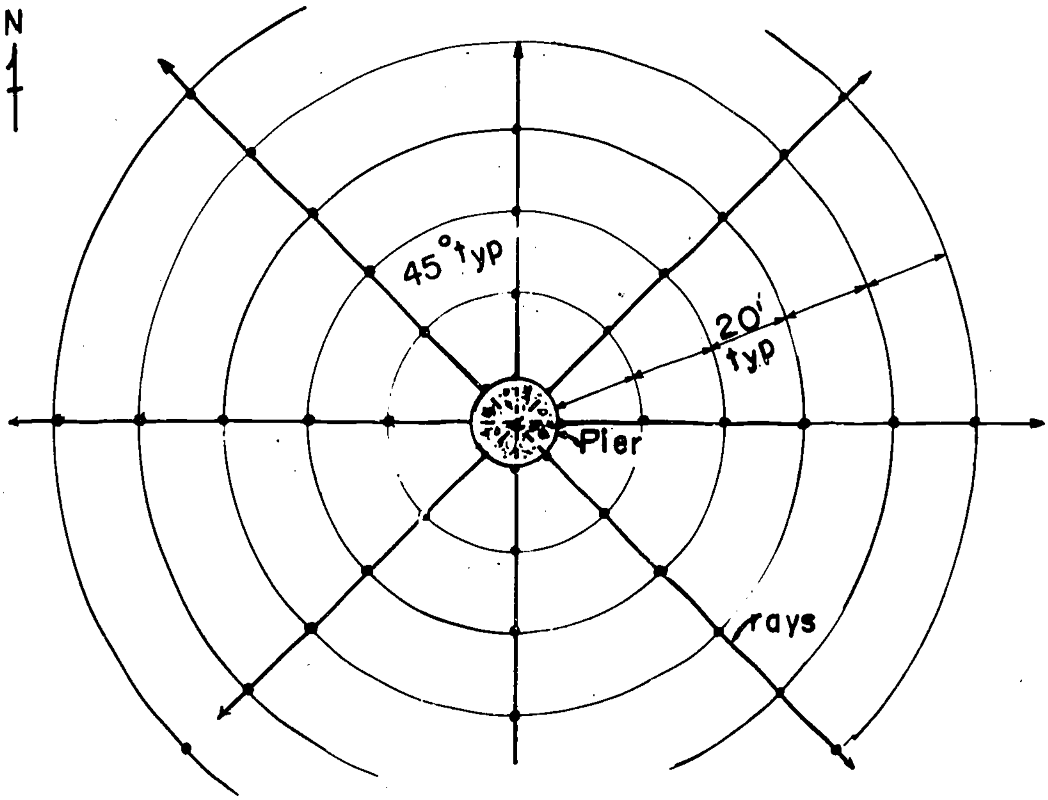
f. *Piles.* All piles should be inspected both above and below the waterline.

### 4–2.3 Superstructure.

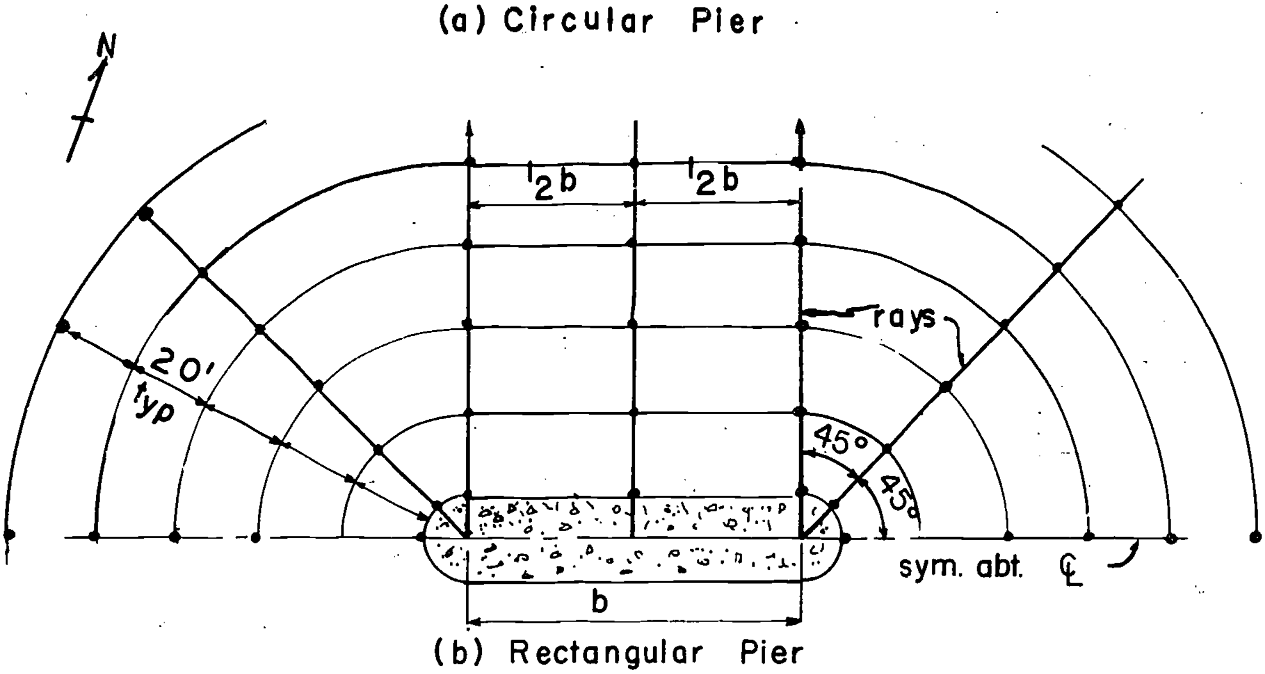
a. *Main Supporting Members.* Inspection of main supporting members should be particularly thorough since their failure could cause the collapse of the bridge. Main supporting members may include, but not necessarily be limited to, the following:

(1) Main girders and stringers
(2) Box girders
(3) T-beams
(4) Trusses
(5) Hangers and cables
(6) Eyebars
(7) Arch ribs
(8) Frames
(9) Suspension cables
(10) Main slabs
(11) Floor beams

b. *Drawings.* If "as built" drawings or design drawings are available, study "Stress Sheets" carefully, noting which members are in compression and which are in tension. Compressive stresses are usually marked minus (—), and tensile stresses are marked plus (+), except on some arches or older bridges where the signs are reversed for convenience.




(a) Circular Pier




(b) Rectangular Pier

*Figure 4–1. Typical grid for soundings.*

c. *Coding.* Numbers or letters should be assigned to joints, panel points, beam lines, hangers, and floor connections to make it possible to identify each part of the structure. Refer to Chapter III for an explanation and examples of coding. A sketch showing the identification system should be a part of the inspection form. Before, or during, the inspection the identifying marks should be crayoned or painted on the bridge in order to keep track of the inspector's location and to guard against overlooking any portion of the structure.

d. *Superstructure Inspection.* Inspect the various parts of the superstructure as outlined in Chapter V. Look for:

(1) Corrosion

(2) Cracking

(3) Splitting

(4) Connection slippage

(5) Deformation due to overload

(6) Damage caused when struck by vehicles or vessels

Where the main load of the bridge is carried by a single member, or element whose failure would result in the collapse of the structure, the member should be inspected very thoroughly for cracks and flaws either by visual inspection or by a non-destructive technique, such as ultrasonics or radiography. The pins and the hangers on the suspended span of a two-girder cantilever bridge, or the pins in a pin-connected truss, are typical examples of such members.

e. *Pre-inspection Cleaning.* It will often be necessary to remove dust, debris, rust, paint scale, or animal wastes before inspecting a bridge member. Scrapers, wire brushes, air jets, or shot blasting are very useful for this purpose. A clean surface is particularly important when electronic devices are used for inspection of steel or concrete.

f. *Steel Member Inspection.*

(1) *Rust.* Note extent and severity of rust. Use calipers to measure thickness of metal when loss of section has occurred. Metal thickness can also be measured ultrasonically.

(2) *Cracks.* Note length, size, and location of cracks. Classify cracks as fine, medium, or open.

(3) *Damaged or Bent Members.* Members may be damaged or bent because of collisions or overstressing. Note the type of damage and measure the offset or deflection.

(4) *Hangers, Pins, and Expansion Devices.* Hangers, pins, and expansion devices may be inoperative, worn, damaged, or deteriorated. Pins may be scored. Any of these components may corrode, causing them to lock or freeze. This condition can be detected by noting that hangers or expansion rockers are inclined or rotated in a direction opposite to what would be expected for the temperature at the time of inspection, e.g., a rocker leaning away from the fixed end of the span in cold weather. Heavy rust accumulation on pin joints and on roller nests also indicates a locked joint.

(5) *Rivets and Bolts.* Tightness of a rivet may be tested by placing the thumb beside the rivet and striking the rivet sharply on the other side with a hammer. If the rivet is loose, its movement will be felt by the thumb. On horizontal surfaces a washer or nut may be used instead of the thumb. Tightness of bolts may be tested with a torque wrench (fig. 4–2).

g. *Concrete Member Inspection.* Most types of deterioration will be readily observed. Much of the deterioration will occur on decks or in areas exposed to roadway drainage.

(1) *Cracking.* Cracking will usually be large enough to be seen with the naked eye. Rust or efflorescence stains will often appear at the cracks, and should be reported. Large cracks in the main members, especially in prestressed concrete members, should be carefully recorded.

(2) *Spalling.* Tap the deck with a hammer over a large area outside the apparent spall to locate hollow zones or areas of incipient spalling. When large areas of spalling are expected, a heavy chain attached to a truck may be dragged across the deck.

h. *Timber Structures.*

(1) *Weathering and Wear.* Note severity of weathering and wear.

(2) *Decay and Insect Attack.* Damage due to decay or insect attack is often not visible because it is confined to the interior of the timber members. Hidden deterioration can be detected by use of an increment borer or by sticking an ice pick into the wood. Insects may also leave small piles of sawdust as evidence of their presence.

(3) *Collision or Overloading.* Large cracks, splits, or crushed areas will be readily visible if timber members have been exposed to collision damage or overloads.

(4) *Section Loss.* Record carefully the location and size of any defect and estimate the section loss. The section loss (width of defect times depth of defect) should be reported as a percentage of the original cross sectional area.

(5) *Fire Damage.* Note signs of fire damage, particularly on bridges located in isolated areas.

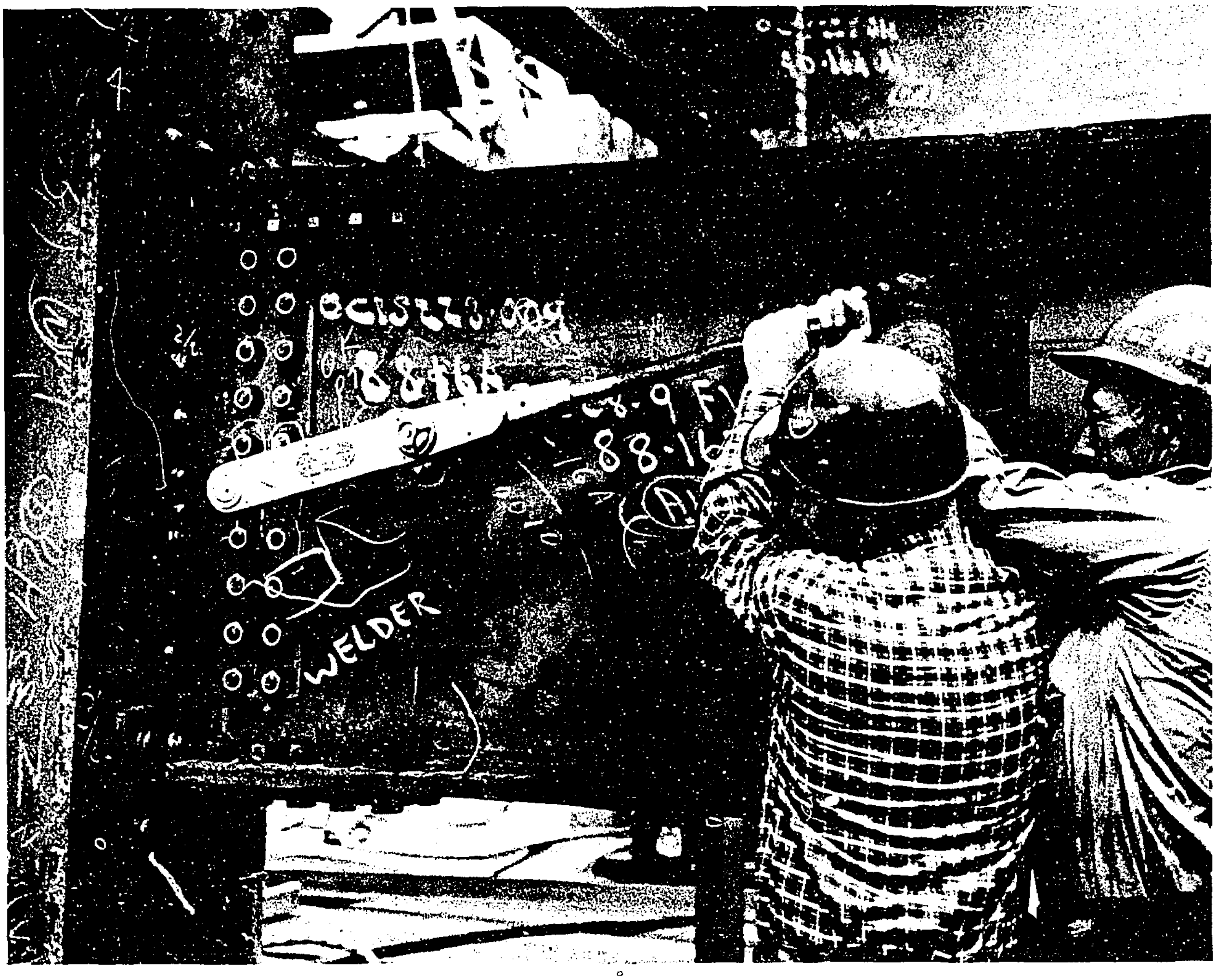
(6) *Nicks and Cuts.* Examine areas where the protective treatment of timber has been broken by nicks, cuts, or drilling.

i. *Wrought Iron Structures.* Wrought iron structures should be carefully examined for rusting and cracking since many of these bridges may have been in use for many years without benefit of adequate maintenance. Sophisticated inspection techniques, such as ultrasonics, are recommended for inspection of wrought iron bridges.

j. *Secondary Members.* Secondary members include cross frames, bracing, and other members whose functions are to stiffen the bridge and to distribute the loads to the main members. These should be inspected in the same way as the main supporting members.

k. *Decks.*

(1) Take a series of profile elevations along the centerline and gutter lines of all long-span bridges. This information should be plotted and compared with the original profile grade lines for that structure.




Courtesy of Bethlehem Steel Co.

*Figure 4–2. Torque wrench being used for checking bolts.*

(2) Examine the decks for various defects, noting size, type, extent, and location of each deficiency. Use the centerline and shoulderline as references for describing location.

l. *Expansion Joints.* Measure and record the width of the opening of all expansion joints. Examine the condition of the expansion joints. Record the temperature and weather at the time of inspection.

m. *Bearing Devices.*

(1) Measure rocker tilts with respect to a fixed reference line.

(2) Measure location of sliding bearings to the nearest 1/8 inch with respect to a fixed reference point.

(3) Measure deformation and bulging of elastomeric pads.

(4) Record the temperature and weather at the time of inspection.

**4–2.4 Approaches, Lighting, and Signing.**

a. Check approaches for:

(1) Excessive vertical displacement between approach pavement and the bridge deck.

(2) Improper joint width.

(3) Clogged joints.

(4) Cracks and potholes.

b. Inspect signing for:

(1) Presence of necessary clearance, weight limit, and other warning signs.

(2) Condition of signs.

c. *Lighting.* Inspect adequacy of:

(1) Highway lighting.

(2) Navigation lights.

(3) Aerial obstruction lights.

(4) Condition of light standards.

**4–2.5 Movable Bridges.**

Movable bridges should be observed while closed, open, and operating. Observe and record the following:

a. The spans' overall behavior.

b. Safety gates and warning signals.

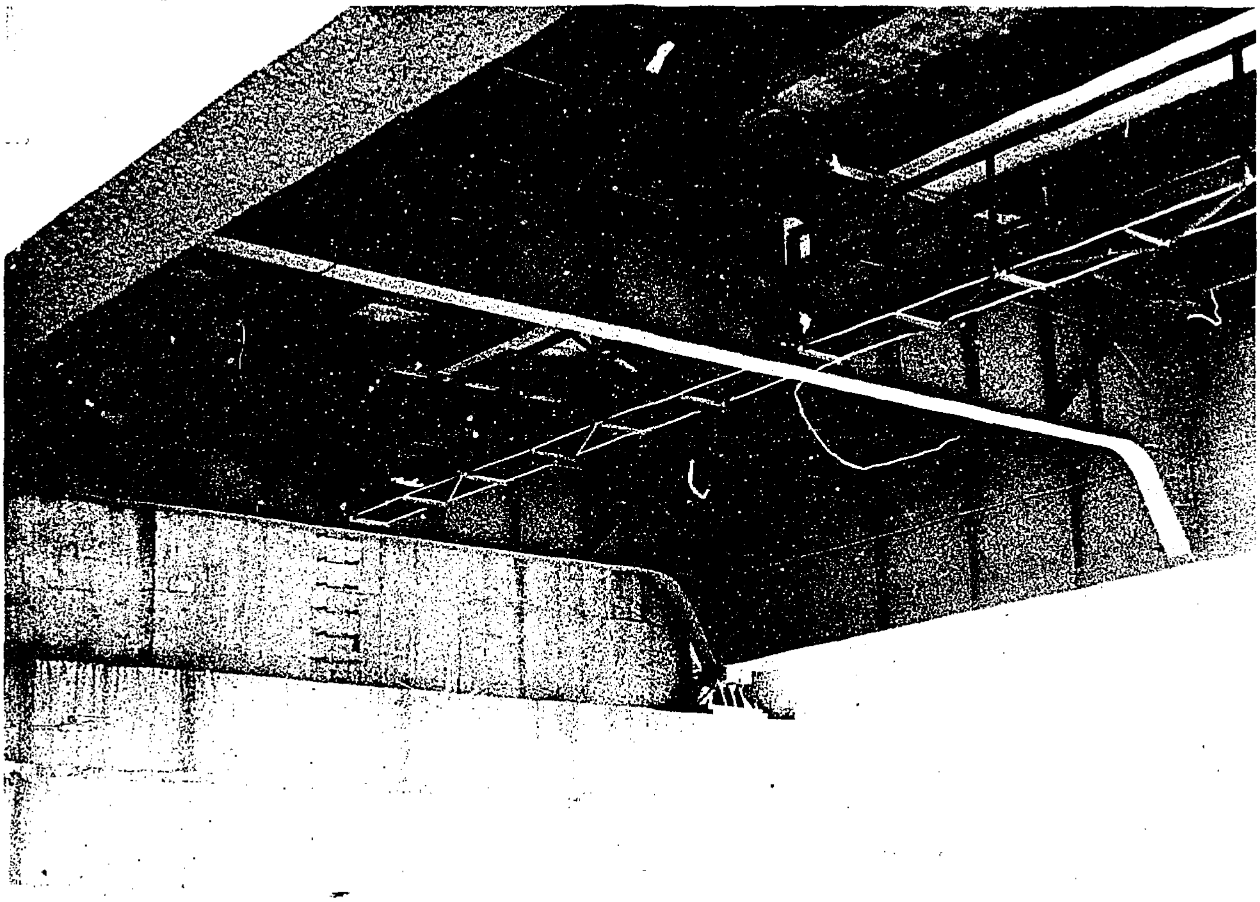


*Figure 4–3. Inspection catwalk and handrails under girder bridge. Note access ladder on backwall.*

c. The mechanical and electrical aspects.

d. Navigation and aerial obstruction lights.

e. Shear locks, wedges, and stops.

f. Any valid complaints or information the operators may offer.

### 4–2.6 Underwater Inspection.

Underwater inspection of piles and substructures will be performed by an experienced diver who will accomplish the following tasks:

a. Note serious rusting of steel piles.

b. Note deterioration of splitting of concrete (including prestressed) piles.

c. Note insect infestation and deterioration of timber piles.

d. Measure the amount of pile loss and estimate remaining section.

e. Scrape marine growth off the piles when necessary for unobstructed vision. A television camera for underwater photography is very helpful; strong lights to illuminate the piles are essential.

f. Check scour development, if necessary.

### 4–2.7 Accessibility.

a. *General.* Special equipment will be needed for some bridges to make all members accessible. Most high-level bridges have been provided with inspection catwalks (fig. 4–3) or travelers under the bridge, or with hand rails along the suspension cables. Some of the newer steel girder bridges have hand rails welded to the webs and stiffeners to make inspection tasks less hazardous (fig. 4–4).

b. *Piles and Piers.* Submerged piles and piers can be inspected only by a diver.

c. *Underside of Bridge.* Ladders can be used for inspecting the underside of a bridge from the ground if the structure is not too high. When the beams cannot be reached from the

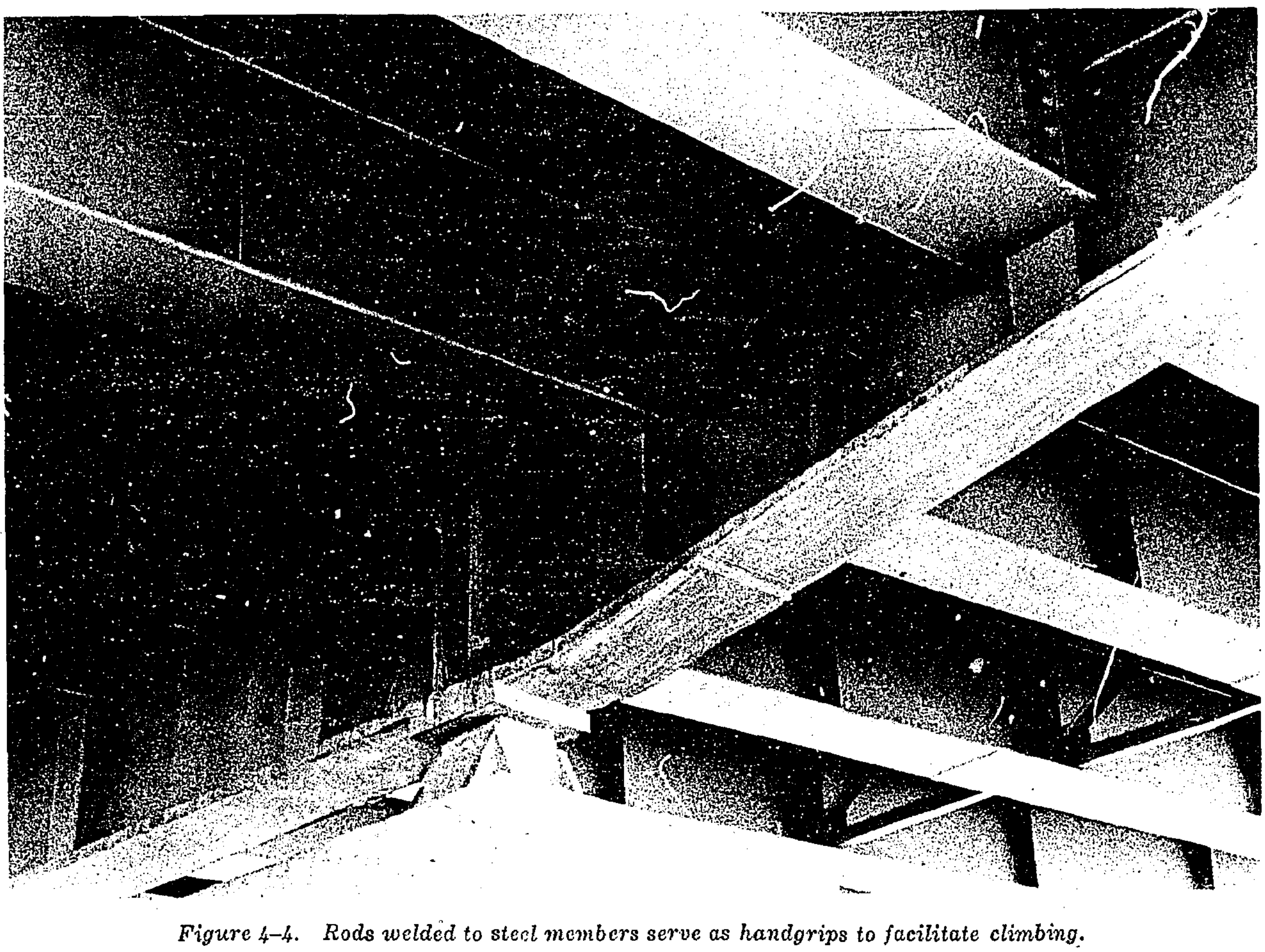


*Figure 4–4. Rods welded to steel members serve as handgrips to facilitate climbing.*

ground, ladders or planking between beams and catwalks can be used. Scaffolding, platforms suspended from the parapet on each side of the structure, or hydraulically operated platform trucks can also be used.

d. *Superstructure.* On high trusses, suspension bridges, and arches, it is usually necessary to climb the superstructure. In doing so, the inspector should make every effort to minimize his risk. He should look for vantage points from which a relatively large area, or a large number of members or details, can be seen clearly without requiring him to change his position.

e. *Platforms.* Hydraulically operated platforms can be used on through trusses, although they have the disadvantage of occupying the shoulder of the roadway.

f. *Helicopters.* Helicopters may be used to photograph the tops and sides of high bridges. Development of corrosion or deterioration can be readily seen by comparing aerial photos that have been taken over a period of several years.

### 4–2.8 Summary.

The most important aspects of a good inspection are:

a. Proper planning of the inspection to ensure that attention is given to each bridge component in accordance with its importance.

b. Preparation according to the inspection plan.

c. Careful and attentive observation.

d. Thorough and complete recording of every item inspected.

# CHAPTER V

# BRIDGE COMPONENT INSPECTION GUIDANCE

## 5-0.0 Introduction.

At this point, the bridge inspector should be familiar with the terminology and elementary theory of bridge construction. He should be familiar with the tools, devices, and specialized equipment used during the bridge inspections, and with all of the safety precautions that must be taken in the course of his inspection. The bridge inspector should have an understanding of the planning, organization, and preparation that is necessary to undertake and complete a meaningful bridge inspection.

However, to be fully qualified to examine bridges, he needs to know what defects and deficiencies to look for. He needs to know what situations and conditions represent actual or potential injury to the bridge or impair public safety. Chapter V instructs, informs, and guides the bridge inspector so as to enable him to recognize the various kinds of bridge deterioration, to pinpoint their location, and to categorize and describe their severity.

The discussion will be concerned primarily with the commonly encountered bridge deterioration problems. The inspection of specialized bridge types and components such as those found on movable and suspension bridges will require the assistance of specially trained bridge inspection personnel. Therefore, Section 5-32, Movable Bridges, and Section 5-34, Suspension Spans, should not be construed as a complete treatment of the subjects. Bridge inspections requiring underwater investigations should be performed with the guidance and assistance of individuals experienced in this specialty.

The type of materials used in the construction of the bridge will establish initially the particular kinds of deterioration the inspector will be looking for during his inspection. For example, rust is the great enemy of steel; concrete deteriorates because of scaling, spalling, and cracking; while timber is subject to weathering, decay, fungus, and insect attacks.

In addition to construction materials, another very important material involved in bridge construction is the soil on which the bridge foundation rests. When the soil or the bridge foundation moves, serious structural difficulties can develop. These movements fall into several categories: lateral movement, vertical movement (settlement), pile settlement, and rotational or tipping movements. The causes of these movements are slope slides, bearing failures, consolidation of soil, seepage, frost action, ice, thermal forces, including pavement thrust, and drag forces on piles.

A common cause of bridge failure is the physical failure of a member due to overloads or collisions. Substructure and superstructure elements should be closely inspected for the types of distress discussed in the sections dealing with the various materials.

Waterways and navigation fenders should be inspected to determine their condition with regard to maintenance. Bridge approaches, drainage, lighting, signing, and utilities should be checked, and any condition considered to be below acceptable standards should be noted and reported.

It will be necessary for the inspector to exercise his own judgment in performing his tasks. However, he should not hesitate to consult his superiors or inspection specialists whenever a problem is beyond his experience or capabilities. It is most important that the inspector realize the necessity for reporting the severity, location, and extent of the deterioration. Descriptions of deterioration should be factual, complete, and documented by a photograph or a sketch whenever practical. The professional engineer who heads the inspection team should encourage frank and open discussions among all members of the team to ensure full exchange of information concerning the inspection task.

## Section 1. CONCRETE

### 5–1.1 General.

Concrete is essentially a compressive material. While it has adequate strength for most structural uses, it is best suited for relatively massive members that transmit compressive loads directly to the founding material. Although concrete has low tensile strength, reinforcing it with steel bars produces a material that is suitable for the construction of flexural members, such as deck slabs, bridge girders, etc. Prestressed concrete is produced by a technique which applies compression to concrete by means of highly stressed strands and bars of high strength steel wire. This compressive stress is sufficient to offset the tensile stress caused by the applied loads. Prestressing has greatly increased the maximum span length of concrete bridges.

### 5–1.2 Physical and Mechanical Properties of Concrete.

The principal properties of concrete that are of interest and concern to the bridge inspector are discussed below. While concrete possesses several other properties such as thermal conductivity, volume change, mass, and energy absorption, these are not directly related to the problems of bridge maintenance and, therefore, are not discussed.

a. *Strength.* Compressive strength is high, but shear and tensile strengths are much lower, being about 12% and 10%, respectively, of the compressive strength.

b. *Porosity.* Concrete is inherently porous and permeable since the cement paste never completely fills the spaces between the aggregate particles. This permits absorption of water by capillary action and the passage of water under pressure.

c. *Extensibility.* Concrete is said to be extensible, i.e., undergoes large extensions without cracking. However, this presupposes a high quality concrete and freedom from restraint.

d. *Fire Resistance.* High quality concrete is highly resistant to the effects of fire. However, intense heat will damage concrete. Figure 5–1 illustrates the type of damage that can be caused by fire.

e. *Elasticity.* Concrete under ordinary loads is elastic, i.e., stress is proportional to strain. Under sustained loads the elasticity of concrete is significantly lowered due to creep. This makes concrete less likely to crack.

f. *Durability.* The durability of concrete is affected by climate and exposure. In general, as the water-cement ratio is increased, the durability will decrease correspondingly. Properly proportioned, mixed, and placed concrete is very durable.

g. *Anisotropy.* Concrete itself is generally isotropic, but once reinforced with steel bars or prestressed with steel wires, it becomes anisotropic, i.e., its strength varies depending on the direction in which it is loaded.

### 5–1.3 Factors Causing Deterioration.

a. *Freezing and Thawing.* Porous concrete absorbs water, which upon freezing creates high expansive pressures. These pressures ultimately produce cracking, scaling, and spalling.

Courtesy of Michigan State Highway Dept.

*Figure 5–1. Concrete damaged by intense heat. Note the cracking and spalling of the reinforced concrete pier cap.*

b. *Salt Action.* The use of salt or other deicing agents contributes to weathering through recrystallization, in a fashion similar to that incurred in freezing and thawing. Salt also increases water retention or may chemically attack the concrete if certain compounds are present.

c. *Differential Thermal Strains.* Large temperature variations, which set up severe differential strains between the surface and the interior of a concrete mass, are an occasional cause of concrete deterioration. Aggregates with lower coefficients of thermal expansion than the cement paste may also set up high tensile stresses.

d. *Unsound Aggregates.* Being structurally weak and/or readily cleavable, these materials are vulnerable to the weathering effects of moisture and cold.

e. *Reactive Aggregates and High Alkali Concrete.* Cracking and a weakened concrete structure result from these combinations, especially where the concrete is exposed to the elements.

f. *Sulfate Compounds in Soil and Water.* Sodium, magnesium, and calcium sulfates have a deleterious effect upon compounds in the cement paste and cause rapid deterioration of the concrete.

g. *Leaching.* Water seeping through cracks and voids in the hardened concrete leaches or dissolves the calcium hydroxide and other material compounds. The resultant of such action is either efflorescence or incrustation at the surface of the cracks.

h. *Chemical Attack.* A number of chemicals attack concrete. However, highway structures are usually subjected to only those chemicals present in deicing agents.

i. *Wear or Abrasion.* Traffic abrasion and impact cause wearing of bridge decks; while curbs, parapets, and piers are damaged by the scraping action of such vehicles as snow plows and sweepers. Deck wear also appears as cracking and ravelling at joint edges.

j. *Foundation Movements.* These movements will cause serious cracking in structures. (See Section 5–7, for further discussion.)

k. *Shrinkage and Flexure Forces.* Both of these kinds of forces set up tensile stresses that result in cracks.

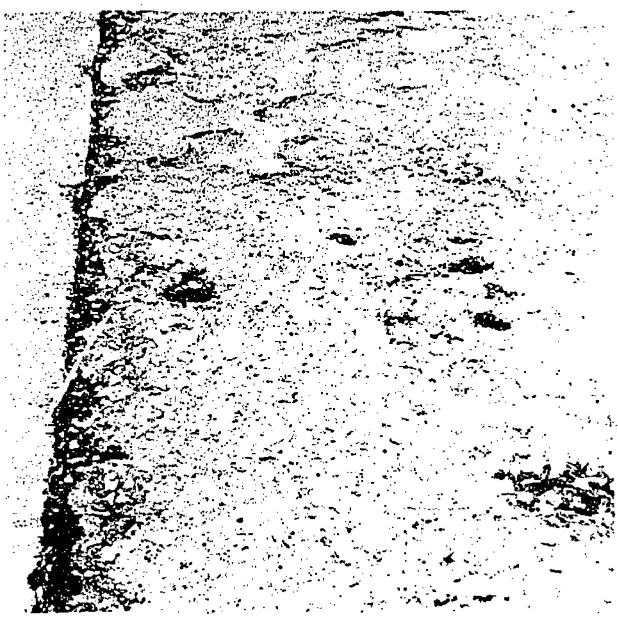
l. *Rusted Reinforcing Steel.* The increase in volume due to rust exerts expansive pressures on concrete.

### 5–1.4 What to Look for During Inspection.

a. *Scaling.* The gradual and continuing loss of surface mortar and aggregate over an area should be classified as follows:

Courtesy of Portland Cement Association.

*Figure 5–2 Light scale. Scale depth is less than ¼".*

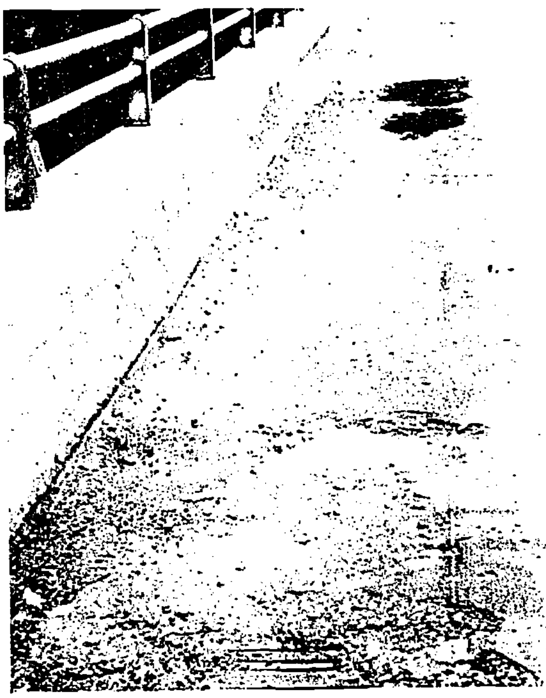


Courtesy of Portland Cement Association.

*Figure 5–3. Medium scale. Scale depth is between ¼" and ½".*

Courtesy of Portland Cement Association.

*Figure 5-4. Heavy scale. Note depth is between ½" and 1". Note virtually complete exposure of course aggregate.*



Courtesy of Portland Cement Association.

*Figure 5-5. Severe scale. Scale depth is greater than 1". Note dislodgement of course aggregate and exposure of reinforcing bars.*

(1) *Light Scale.* Loss of surface mortar up to ¼" deep, with surface exposure of coarse aggregates (fig. 5-2).

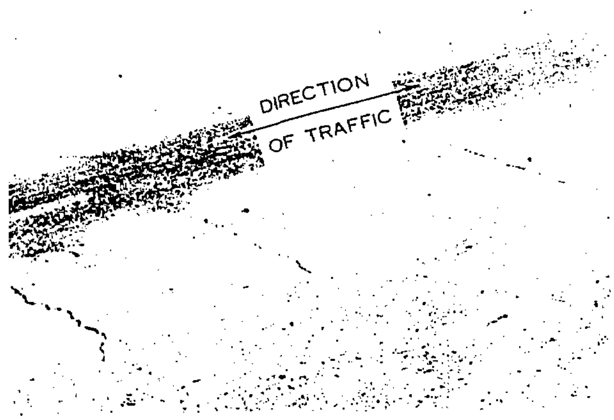
(2) *Medium Scale.* Loss of surface mortar from ¼" to ½" deep, with some added mortar loss between the coarse aggregates (fig. 5-3).

(3) *Heavy Scale.* Loss of surface mortar surrounding aggregate particles of ½" to 1" deep. Aggregates are clearly exposed and stand out from the concrete (fig. 5-4).

(4) *Severe Scale.* Loss of coarse aggregate particles as well as surface mortar and the mortar surrounding the aggregates. Depth of the loss exceeds 1" (fig. 5-5).

NOTE: The inspector should describe the character of the scaling, the approximate area involved, and the location of the scaling on the bridge.

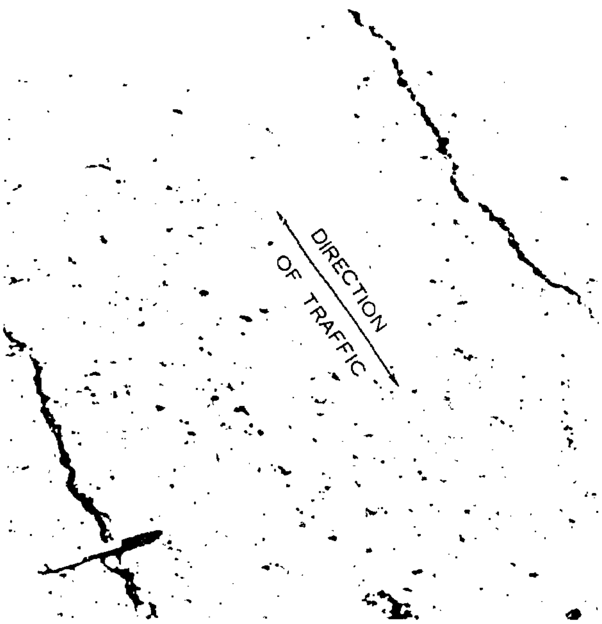
b. *Cracking.* A crack is a linear fracture in the concrete. Cracks may extend partially or completely through the concrete member. While a great many cracks may be in the deck, they will also occur in abutments and wing walls and may appear in areas adjacent to vertical expansion joints. Cracks often appear in pier caps, parapets, T-beams, box girders, and all other concrete elements. When reporting cracks, describe their type, size, length, direction, and location. Compare the results of the current inspection with those of previous inspections to determine whether crack formation is continuing or whether it has been halted. Since cracks are one of the most reliable indications of fu-




Courtesy of Portland Cement Association.

*Figure 5-6. Transverse cracking.*

ture trouble, it is important to determine their cause and extent. Cracks are categorized as follows:



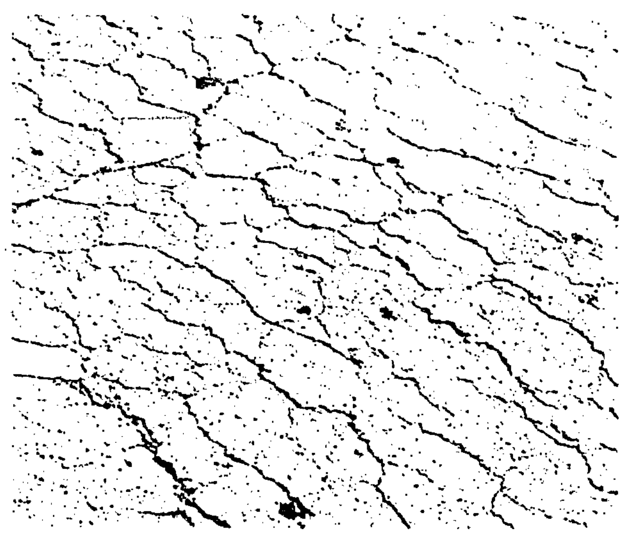

Courtesy of Portland Cement Association.

*Figure 5–7. Longitudinal cracking.*

Courtesy of Portland Cement Association.

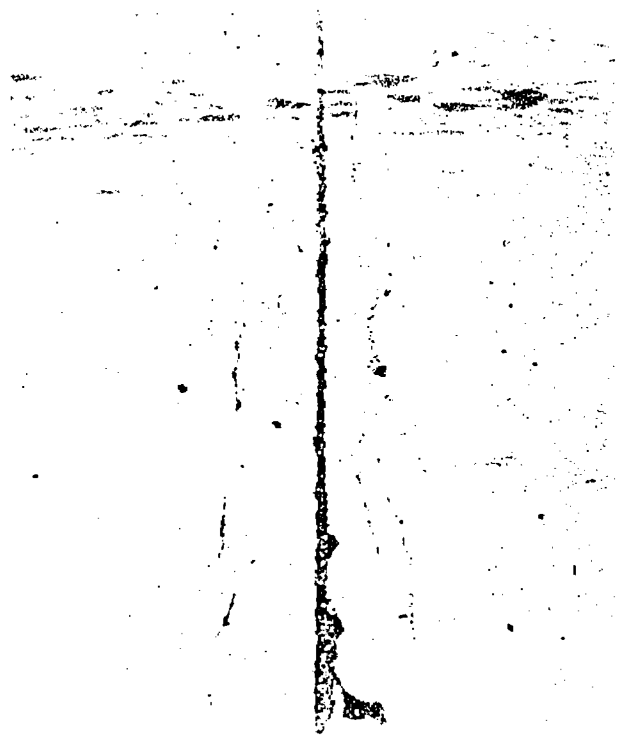
*Figure 5–8. Diagonal cracking.*

(1) *Transverse Cracks.* These are fairly straight cracks that are roughly perpendicular to the center line of the roadway (fig. 5–6). Transverse cracks vary in width, length, and in spacing. They frequently occur over the main slab reinforcement on stringer bridges. Cracks may extend completely through the slab. These



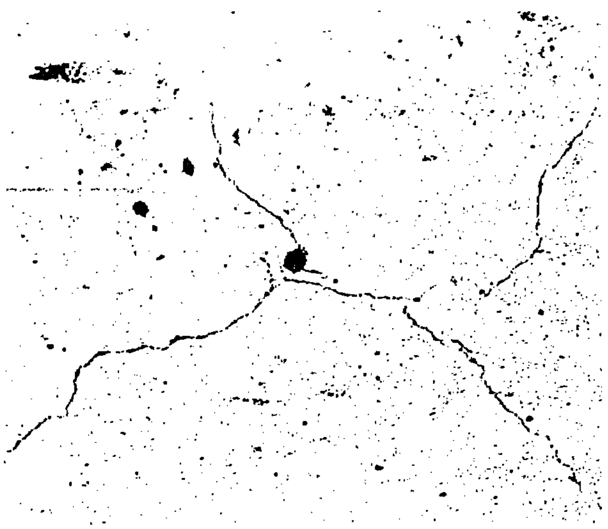
Courtesy of Portland Cement Association.

*Figure 5–9. Pattern or map cracking.*



Courtesy of Portland Cement Association.

*Figure 5–10. D-cracking.*



Courtesy of Portland Cement Association.

*Figure 5-11. Random cracking.*

same cracks may extend through curbs, sidewalks, and parapets. On skewed bridges where the transverse deck steel is not placed at right angles to the roadway center line, this type of crack may appear parallel to the deck steel. On continuous structures, pronounced transverse cracking may be noted in or near the negative moment zones over the piers. Pier caps are also subject to transverse cracking.

(2) *Horizontal Cracking.* Cracking of this kind will occur in walls, abutments, pier stems, and columns. They are similar in nature to transverse cracks, and may be listed as such.

(3) *Longitudinal Cracks.* These are fairly straight cracks (in slabs) running parallel to the center line of the roadway. They are of variable widths, lengths, and spacings. These cracks may extend partially or completely through the deck (fig. 5-7).

(4) *Vertical Cracks.* Vertical cracks in walls, abutments, pier stems, and caps are similar to longitudinal cracking in slabs, and should be described as such.

(5) *Diagonal Cracks.* These cracks appear roughly parallel in slabs skewed to the center line of the bridge. They are usually shallow and are of varying lengths, widths, and spacings (fig. 5-8). When found in the vertical faces of beams or pier caps they may be deeper than usual, and thus pose a more serious problem.

(6) *Pattern or Map Cracking.* These interconnected cracks form networks of varying size, and appear similar to that of sun-cracking seen on dried flats. They vary in width from barely visible, fine cracks to well-defined openings (fig. 5-9). They are found in both slabs and walls.

(7) *D-cracks.* These are usually defined by dark colored deposits, generally near joints and edges (fig. 5-10). They may widen gradually and eventually produce failure. Vertical cracks near vertical expansion joints in abutments and walls can also be classified as D-cracks. This type of cracking may be indicative of alkali reactive concrete.

(8) *Random Cracks.* These are meandering irregular cracks appearing on the surface of slabs. They have no particular form and do not logically fall into any of the classifications described above (fig. 5-11).

c. *Spalling.* Spalling is a roughly circular or oval depression in the concrete. It is caused by the separation and removal of a portion of the surface concrete revealing a fracture roughly parallel, or slightly inclined, to the surface. Usually, a portion of the depression rim is perpendicular to the surface. Often reinforcing steel is exposed as shown in fig. 5-12. Spalling may be classified as follows:

Courtesy of Portland Cement Association.

*Figure 5-12. Small surface spall.*

(1) *Small.* Not more than 1" deep or approximately 6" in diameter (fig. 5-12).

(2) *Large.* More than 1" deep and greater than 6" in diameter (figs. 5-13 and 5-14).

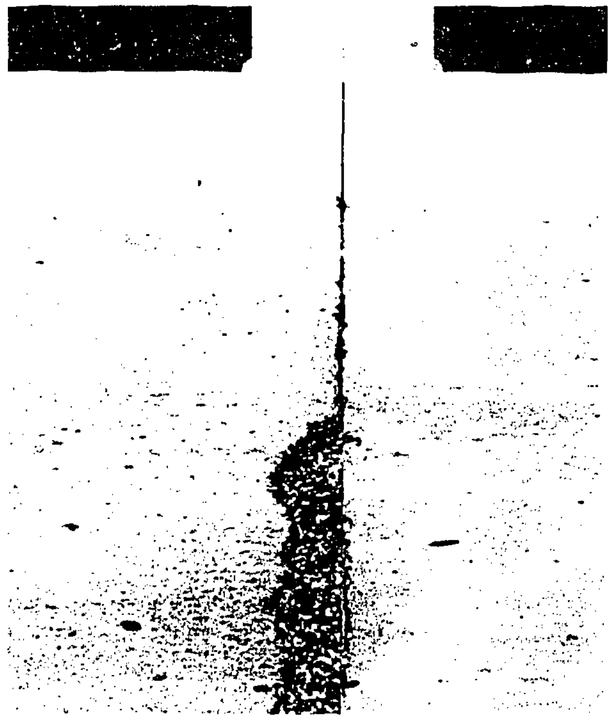
(3) *Hollow Area.* An area of concrete which gives off a hollow sound when struck with a hammer or steel bar, indicating the existence of a fracture plane below the surface.

Courtesy of Portland Cement Association.

*Figure 5-13. Large surface spall.*

Courtesy of Portland Cement Association.

*Figure 5-14. Surface spall exposing reinforcing steel.*



Courtesy of Portland Cement Association.

*Figure 5-15. Joint spall.*

Courtesy of Portland Cement Association.

*Figure 5-16. Popout.*

Courtesy of Portland Cement Association.

*Figure 5–17. Mudballs.*

d. *Joint Spall.* This is an elongated depression along an expansion, contraction, or construction joint (fig. 5–15).

e. *Pop-Outs.* These are conical fragments that break out of the surface of the concrete leaving small holes. Generally, a shattered aggregate particle will be found at the bottom of the hole, with a part of the fragment still adhering to the small end of the pop-out cone (fig. 5–16).

f. *Mudballs.* These are small holes that are left in the surface by the dissolution of clay balls or soft shale particles (fig. 5–17).

In recording the last four defects, describe the type, depth, dimension, and location together with a sketch, drawing, or photograph, as appropriate.

## Section 2. STEEL

### 5–2.1 General.

Steel, a highly reliable and versatile construction material, is available in many forms—wire, cable, plate, and shaped bars or beams. Many of the nation's larger bridges are constructed primarily of steel.

### 5–2.2 Physical and Mechanical Properties of Steel.

a. *Strength.* Steel possesses tremendous compressive and tensile strength and is highly resistant to shear forces. Thin steel sections, however, are vulnerable to compressive buckling.

b. *Ductility.* Both the low carbon and low alloy steels normally used in bridge construction are quite ductile. Brittleness may occur because of heat treatment, welding, or through metal fatigue.

c. *Durability.* Steel, when protected properly, is extremely durable.

d. *Fire Resistance.* Steel is subject to a loss of strength when exposed to high temperatures such as those resulting from fire (fig. 5–18).

e. *Corrosion.* Unprotected carbon steel corrodes (rusts) readily. However, it can readily be protected.

f. *Weldability.* Although steel is weldable, it is necessary to determine the chemistry of the steel and to select a suitable welding procedure before starting welding operations on a bridge.

g. *Others.* Steel is elastic and conducts heat and electricity.

### 5–2.3 Factors Causing Deterioration.

a. *Air and Moisture.* Air and moisture cause rusting of steel, especially in a marine climate.

b. *Industrial Fumes.* Industrial fumes in the atmosphere, particularly hydrogen sulfide, cause deterioration of steel.

c. *Deicing Agents.* While all deicing agents attack steel, salt is the most commonly encountered chemical on bridges.

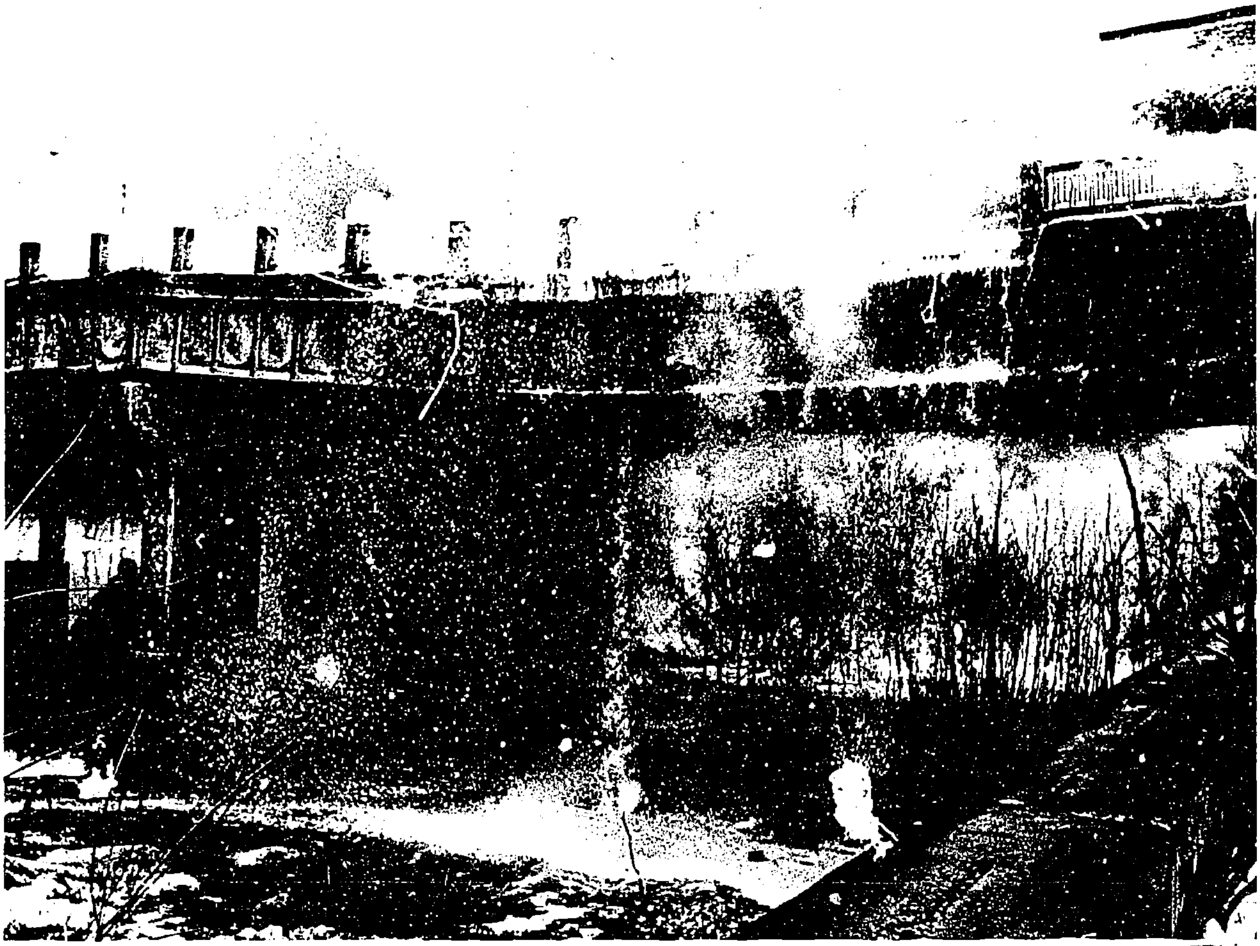
d. *Seawater and Mud.* Unprotected steel members, such as piles immersed in water and embedded in mud, undergo serious deterioration and loss of section.

e. *Thermal Strains or Overloads.* Where movement is restrained, or where members are overstressed, the steel may yield, buckle, or crack (or rivets and bolts may shear).

f. *Fatigue and Stress Concentrations.* Cracks may develop because of fatigue or poor details which produce high stress concentrations. Examples of such details are: re-entrant corners, abrupt and large changes in plate widths and/or thicknesses, a concentration of heavy welds, or an insufficient bearing area for a support.

g. *Fire.* Extreme heat will cause serious deformations of steel members.

h. *Collisions.* Trucks, over-height loads, de-



Courtesy of Michigan State Highway Dept.

*Figure 5–18. Steel beams subjected to intense heat. Note deflection of members.*

railed railroad cars, etc., may strike steel beams or columns, damaging the bridge.

i. *Animal Wastes.* These may cause rusting, and can be considered as a special type of direct chemical attack.

j. *Welds.* Where the flux is not neutralized, some rusting may occur. Welds may crack because of poor welding techniques or poor weldability of the steel.

k. *Galvanic Action.* Other metals that are in contact with steel may cause corrosion similar to rust.

### 5–2.4 What to Look for During Inspections.

a. *Rust.* Rusted steel varies in color from dark red to dark brown. Initially, rust is fine grained, but as it progresses, it becomes flaky

Courtesy of District of Columbia Highway Dept.

*Figure 5–19. Rust on floor stringer. Note that web is completely rusted through.*

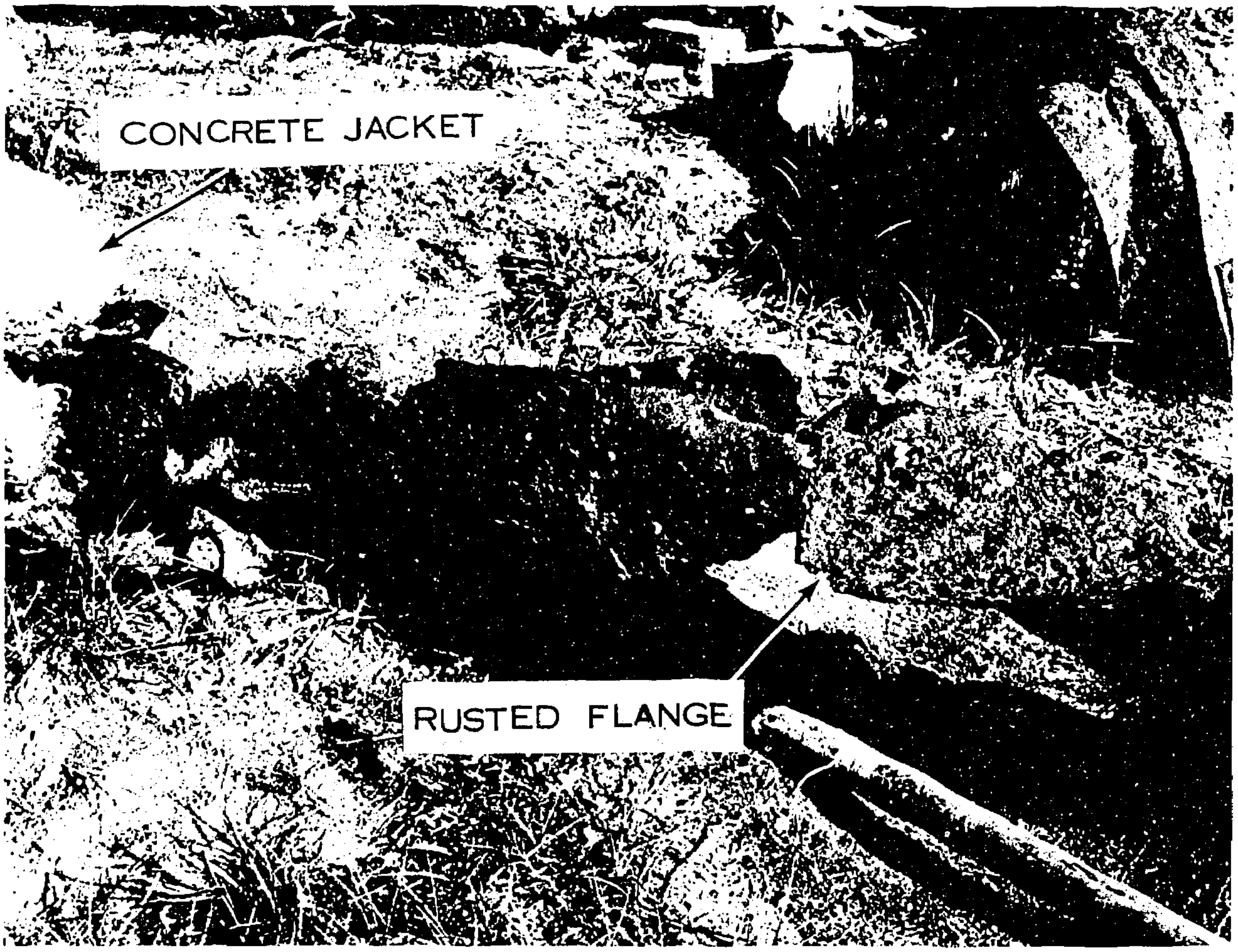



*Figure 5–20. Steel bearing pile deterioration. Severe rusting occurred between concrete jacket and mud line. Note loss of section.*

or scaly in character. Eventually, rust causes a pitting of the member. The inspector should note the location, characteristics, and the extent of the rusted areas. The depth of heavy pitting should be measured and the size of any perforation caused by rusting should be recorded. Rust may be classified as follows:

(1) *Light.* A light, loose rust formation pitting the paint surface.

(2) *Moderate.* A looser rust formation with scales or flakes forming. Definite areas of rust are discernible.

(3) *Severe.* A heavy, stratified rust or rust scale with pitting of the metal surface. This rust condition eventually culminates in the perforation of the steel section itself (figs. 5–19 and 5–20).

b. *Cracks.* Cracks in the steel may vary from hairline thickness to sufficient width to transmit light through the member. Any type of crack is obviously serious, and should be reported at once. Record the location and length of all cracks and indicate whether the cracks are open or closed.

c. *Buckles and Kinks.* These conditions develop mostly because of damage arising from thermal strain, overload, or added load conditions. The latter condition is caused by the failure or the yielding of adjacent members or components. Collision damage may also cause buckles, kinks and cuts. Look for cracks radiating from cuts or notches. Note the members damaged, the type, location, and extent of the damage, and measure the amount of deformation, if possible.

d. *Stress Concentrations.* Observe the paint around the connections at joints for fine cracks which are indications of large strains due to stress concentrations. Be alert for sheared or deformed bolts and rivets.

e. *Structural Steel.* Inspect structural steel partially incased in substructure concrete at the face of exposure for deterioration and for movement.

f. *Galvanic Corrosion.* This condition will appear essentially similar to rust.

## Section 3. TIMBER

### 5-3.1 Physical and Mechanical Properties of Timber.

a. *Strength.* Timber, while not as strong as steel approximates ordinary concrete in compressive strength. Rated strongest in flexural strength, timber has an allowable compressive strength (parallel to grain) of about 75% of the flexural value. Perpendicular to the grain, compressive strength is only 20% of the flexural strength. Horizontal shear is limited to 10% of the flexural strength.

b. *Porosity.* Being a cellular, organic material, timber is quite porous.

c. *Anisotropy.* As may be deduced from the differences in allowable compressive strengths, wood is anisotropic, i.e., it has different strength properties depending upon the manner and direction of loading.

d. *Impact Resistance.* Since timber is able to withstand a greatly increased load momentarily, neither impact nor fatigue are serious problems with timber.

e. *Durability.* Under certain conditions, and when properly treated or protected, timber is quite durable. However, timber is not a particularly durable material under all conditions. It should be noted that some preservative treatments reduce the strength of timber.

f. *Fire Resistance.* Timber is very vulnerable to damage by fire.

g. Timber is also elastic, low in thermal and electrical conductivity and subject to volume changes.

### 5-3.2 Factors Causing Deterioration.

Deterioration can be prevented or greatly reduced by proper preservative treatment. However, in existing structures, it is often difficult to tell what preservative treatment has been used.

a. *Fungi.* Fungi usually require some moisture. As a rule, fungus decay can only be avoided by excellent preservative treatment.

b. *Vermin.* These tunnel in and hollow out the insides of timber members for food and/or shelter.

(1) Termites

(2) Powder-post beetles and carpenter ants

(3) Marine borers

c. *Weathering, Warping, etc.* This is normally caused by repeated dimensional changes in the wood—usually due to repeated wetting.

d. *Chemicals.* These act in three different ways: a swelling and resultant weakening of the wood, a hydrolysis of the cellulose by acids, or a delignification by alkalis. Animal wastes are also a problem.

e. *Fire.* Timber is particularly vulnerable to fire.

f. *Abrasion or Mechanical Wear.* Abrasion is most serious when combined with decay which softens or weakens the wood. On bridges, decks are especially vulnerable.

g. *Collisions and Overloadings.* Damage will be evident in the form of shattered or injured timbers, sagging or buckled members, or timbers with large longitudinal cracks. Give location and extent of damage and determine whether immediate repairs are necessary.

### 5-3.3 What to Look for During Inspection.

a. *Fungus decay.*

(1) *Mild.* Mild fungus decay appears as a stain or discoloration. It is hard to detect and even harder to distinguish between decay fungi and staining fungi.

(2) *Advanced.* Wood darkens further and shows signs of definite disintegration, with the surface becoming punky, soft and spongy, stringy, or crumbly, depending upon the type of decay or fungus (fig. 5-21). It is similar to dry

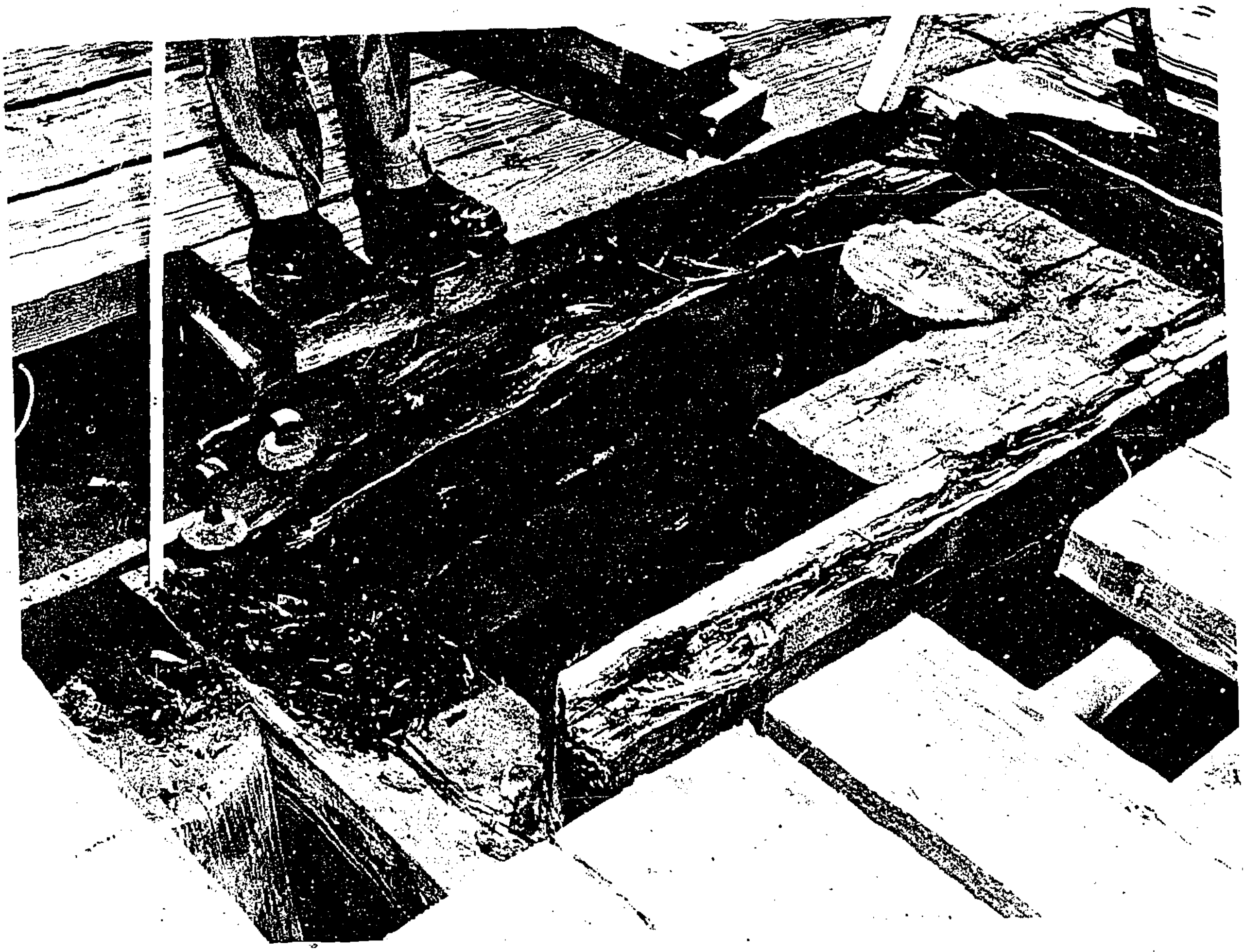


*Figure 5–21. Advanced decay. Decay started at spike holes of timber superstructure.*

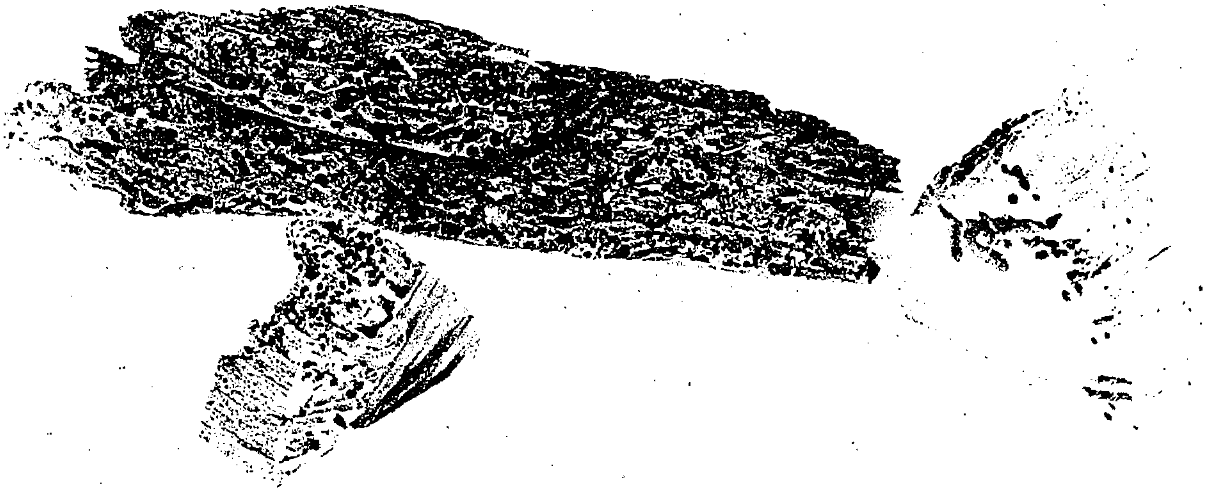


*Figure 5–22. Teredo damage in top-grade greenheart.*

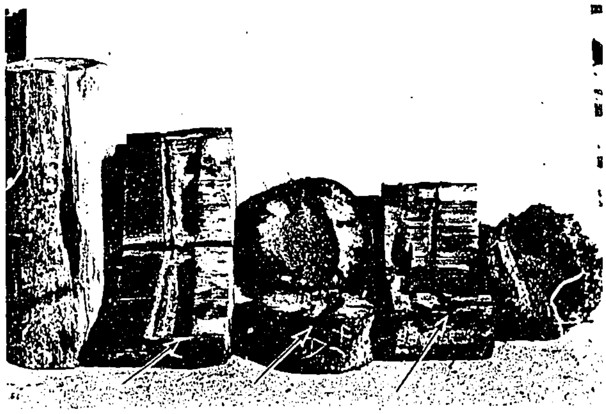


*Figure 5–23. Sections of treated timber piling. Note that damage starts at bolt holes.*

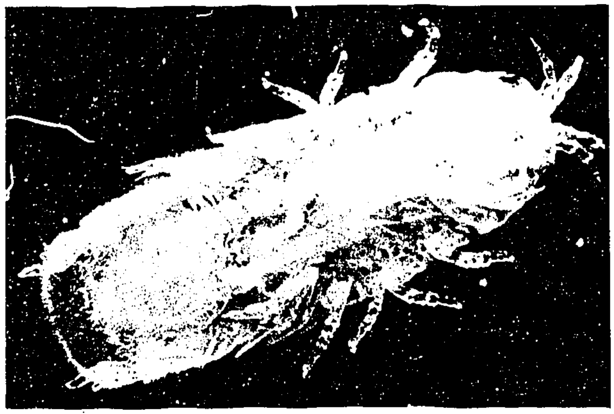


*Figure 5–24. Limnoria, underside view.*

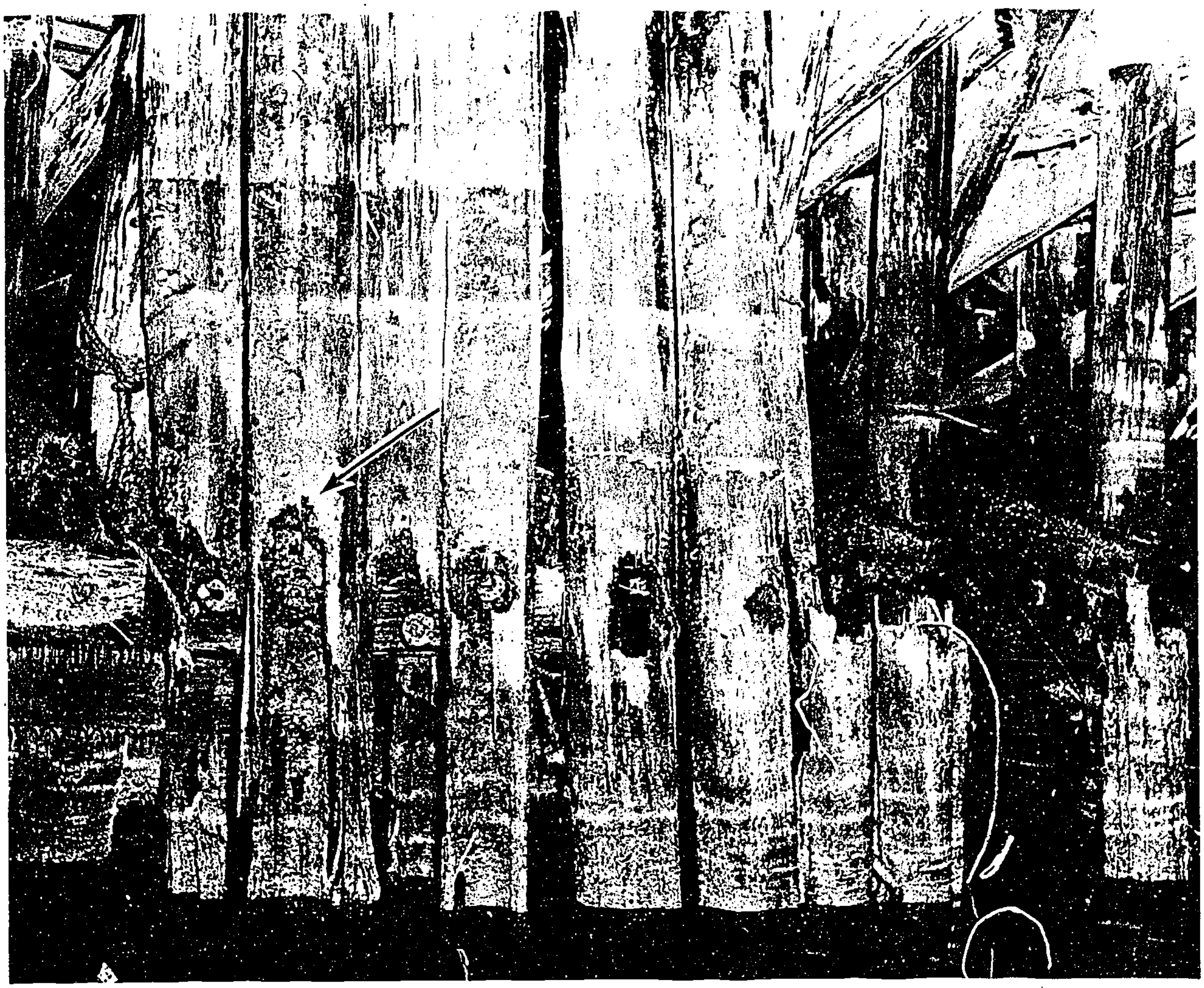


*Figure 5–25. Limnoria damage in tidal zone.*

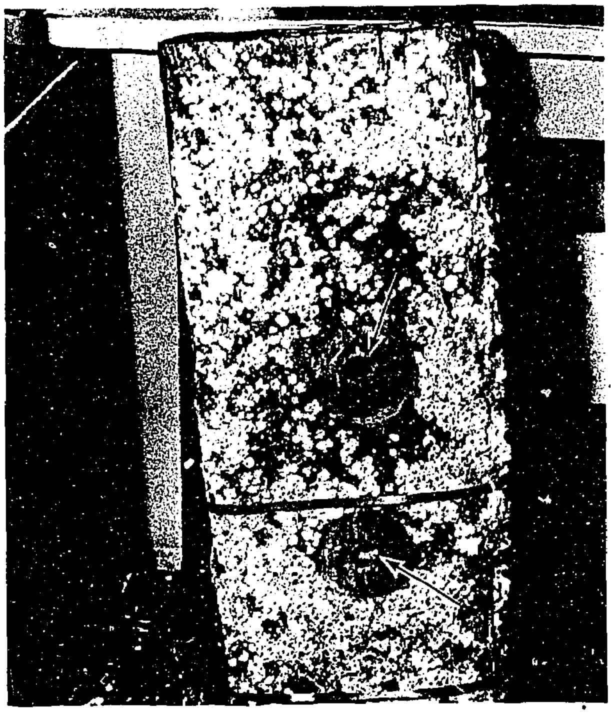


*Figure 5-26. Limnoria attack in treated timber placed in tidal zone. Damage starts at bolt holes and cuts. The discs on the surface of the timber are marine growth.*

rot of door posts and outside porches. Fruiting bodies of fungi, similar to those seen on old stumps, may develop. The inspector should note the location, depth of penetration, and size of the areas of decay. Where decay occurs at a joint or splice, indicate the effect on the strength of the connection. Use a knife, icepick, or an increment borer to test for decayed wood. Decay is very likely to occur at connections, splices, support points, or around bolt holes. This may be due either to the tendency of such areas to collect and retain moisture, or to bolt holes or cuts being made in the surface after the preservative treatment has been applied. Unless these surfaces are subsequently protected, decay is very likely. Any holes, cuts, scrapes or other breaks in the timber surface which would break the protective layers of the preservative treatment, and allow access to untreated wood should be noted.

b. *Vermin.*

(1) *Termites.* All damage is inside the surfaces of the wood; hence, it is not visible. White mud shelter tubes or runways extending up from the earth to the wood and on the sides of masonry substructures are the only visible signs of infestation. If the timber members exhibit signs of excessive sagging or crushing, check for termite damage with an ice pick or an increment borer.

(2) *Powder-Post Beetles.* The outer surface is pocked with small holes. Often a powdery dust is dislodged from the holes. The inside may be completely excavated.

(3) *Carpenter Ants.* Accumulation of sawdust on the ground at the base of the timber is an indicator. The large, black ants may be seen in the vicinity of the infested wood.

(4) *Marine Borers.* The inroads of marine borers will usually be most severe in the area between high and low water since they are water-borne, although damage may extend to the mud line. Where piles are protected by concrete or metal shielding, the shields should be inspected carefully for cracks or holes that would permit entrance of the borers. Unplugged bolt holes also permit entrance of these pests. (Figs. 5–23 and 5–26.) In such cases, there are often no outside evidences of borer attack. The inspector should list the locations and extent of damage and indicate whether it is feasible to exterminate the infestation and strengthen the member or if immediate replacement is necessary.

(a) *Mollusk Borers (Shipworms).* The shipworm is one of the most serious enemies of marine timber installations. The most common species of shipworm is the teredo. This shipworm enters the timber in an early stage of life and remains there for the rest of its life. Teredos reach a length of 15 inches and a diameter of 3/8 inch, although some species of shipworm grow to a length of 6 feet. The teredo maintains a small opening in the surface of the wood to obtain nourishment from the sea water. Figures 5–22 and 5–23 show shipworm damage.

(b) *Crustacean Borers.* The most commonly encountered crustacean borer is the limnoria or wood louse (fig. 5–24). It bores into the surface of the wood to a shallow depth. Wave action or floating debris breaks down the thin shell of timber outside the borers' burrows, causing the limnoria to burrow deeper. The continuous burrowing results in a progressive deterioration of the timber pile cross section which

*Figure 5–27. Limnoria attack in tidal zone. Attack began at cut off ends of bracing and progressed through bolt holes into piling.*

will be most noticeable by the hour glass shape developed between the tide levels. Limnoria damage is illustrated in figures 5–25, 5–26, and 5–27.

c. *Weathering.*

(1) *Slight.* Surfaces of wood are rough and corrugated, and the members may even warp (fig. 5–28).

(2) *Advanced.* Large cracks extend deeply or completely through the wood. Wood is crumbly and obviously deteriorated (similar to tips of roof shingles at the eaves).

d. *Chemical Attack.* This will resemble decay.

e. *Fire.* Fire damage is easily recognized. Usually this type of damage will have been reported prior to the inspection.

f. *Mechanical Wear.* Wear due to abrasion is readily recognized by the gradual loss of section at the points of wear. The inspector should report the location, the general area subject to wear, and the loss in thickness. He should also indicate whether immediate remedial action is necessary.

g. *Collision.* Shattered or injured timbers are indications of collision. Give location and extent of damage and determine whether immediate measures are needed.

h. Unplugged holes, such as those left by test borings, nails, bolts, and the like.

*Figure 5–28. Weathering and wear of untreated timber deck.*

## Section 4. WROUGHT AND CAST IRON

### 5–4.1 General.

a. Wrought iron is a metal in which slag inclusions are rolled between the microscopic grains of iron. This results in a fibrous material with properties quite similar to steel, although tensile strength is lower than in steel.

b. Cast iron is iron in which carbon has been dissolved. Other elements which affect the properties of cast iron are silicon and manganese. In general, a wide range of properties are obtained depending upon the alloying elements used.

### 5–4.2 Physical and Mechanical Properties.

a. Wrought Iron.

(1) *Strength*. Wrought iron has an ultimate tensile strength of about 50,000 psi. However, the rolling process and presence of the slag inclusions make wrought iron anisotropic; wrought iron has a tensile strength across the grain of about 75% of its longitudinal strength. While this characteristic has been largely eliminated in the wrought iron made today, wrought iron in the old bridges will be anisotropic.

(2) *Elasticity*. Wrought iron has an elastic modulus of 24,000,000 psi–29,000,000 psi. This is nearly as high as steel.

(3) *Ductility*. Wrought iron is generally ductile, although its ductility depends, to a large extent, upon the method of manufacture.

(4) *Toughness and Impact Resistance*. Wrought iron is tough and resistant to impact.

(5) *Corrosion Resistance.* The fibrous nature of wrought iron produces a tight rust which is less likely to progress to flaking and scaling than is rust on carbon steel.

(6) *Weldability.* Wrought iron is welded with no great difficulty. However, care should be exercised when planning to weld the metal of an existing bridge.

b. *Cast Iron*

(1) *Strength.* The tensile strength of cast iron varies from 20,000 psi to 60,000 psi, depending upon its composition. In dealing with the iron in old bridges, it must be assumed that the cast iron will be near the lower end of the scale. The compressive strength of cast iron is high, from 60,000 psi up. For this reason, cast iron was used for compression members in the early iron bridges, while wrought iron was used for tension members.

(2) *Elasticity.* Cast iron has an elastic modulus of 13,000,000 psi to 30,000,000 psi.

(3) *Brittleness.* Cast iron is brittle.

(4) *Impact Resistance.* Cast iron possesses good impact resistance properties.

(5) *Corrosion Resistance.* Cast iron, in general, is more corrosion resistant than the other ferrous metals.

(6) *Weldability.* Due to its high carbon content, cast iron is not easily welded.

### 5–4.3 What to Look for During Inspection.

a. In general, a wrought iron structure will be inspected similarly to a steel structure.

b. Cast iron should also be inspected similarly to steel. It should be noted that cast iron is subject to defects such as checks (cracking due to tensile cooling stresses) and blowholes. The latter has a serious effect on both the strength and toughness of the cast iron.

## Section 5. STONE MASONRY

### 5–5.1 General.

Stone masonry is little used today, except as facing or ornamentation. However, some old stone structures are still in use. The types of stones commonly used in bridges are granite, limestone, and sandstone, although many smaller bridges or culverts were built of stones locally available.

### 5–5.2 Physical and Mechanical Properties.

a. *Strength.* Stone has more than adequate strength for most loads.

b. *Porosity.* While all stone is porous, sandstone and some limestones are much more so than granite.

c. *Absorption.* Most stone is absorptive, especially limestone.

d. *Thermal Expansions.* Stone expands and contracts with temperature variations.

e. *Thermal Conductivity.* Stone is generally a poor conductor of heat.

f. *Durability.* Stone is more durable than most materials, although there is a wide range in durability between different varieties of stone.

g. *Fire Resistance.* While not flammable, stone can be damaged by fire.

### 5–5.3 Factors Causing Deterioration.

a. *Chemicals.* Gases and solids dissolved in water often attack rocks chemically. Some of these solutions can dissolve cementing compounds between the rocks. Oxidation and hydration of some compounds found in rock will also cause damage.

b. *Seasonal Expansion and Contraction.* Repeated volume changes produced by seasonal expansion and contraction will cause tiny seams to develop, thereby weakening the rock.

c. *Frost and Freezing.* Water freezing in the seams and pores of rocks can split or spall rock.

d. *Abrasion.* Abrasions are due mostly to wind or waterborne particles.

e. *Plant Growth.* Lichens and ivy will attack stone surfaces chemically in attaching themselves to the stone. Roots and stems growing in crevices or joints exert a wedging force.

f. *Marine Borers.* Rock-boring mollusks attack rock by means of chemical secretions.

### 5–5.4 What to Look for During Inspection.

a. *Weathering.* The hard surface degenerates into small granules, giving stones a smooth, rounded look.

b. *Spalling.* Small pieces of rock break out or chip away.

c. *Splitting.* Seams or cracks open up in rocks, eventually breaking them into smaller pieces.

### Section 6. ALUMINUM

**5-6.1 General.**

While aluminum has been widely used for signs, light standards, railings, and sign bridges, it is seldom used as the principal material in the construction of vehicular bridges. While most properties of aluminum are similar to those of steel, the following differences exist:

a. *Lightness.* Aluminum weighs about one-third (1/3) as much as steel.

b. *Strength.* Aluminum, while not as strong as steel, will be made comparable to steel in strength when alloyed.

c. *Corrosion Resistance.* Aluminum is highly resistant to atmospheric corrosion.

d. *Workability.* Aluminum is easily fabricated, however, welding requires special procedures.

e. *Durability.* Aluminum is durable.

**5-6.2 What to Look for During Inspection.**

a. *Cracking.* Aluminum may be subject to some fatigue cracking. Aluminum members should be examined in areas near the bases of cantilever arms and in areas near complex welded and riveted connections. Weld cracking often occurs on sign bridges near those joints which are subject to high stresses because of the misalignment of prefabricated sections. The combination of high stresses and the vibration that is caused by winds produces fatigue.

b. *Pitting.* Aluminum will pit slightly, but this condition rarely becomes serious.

### Section 7. FOUNDATION MOVEMENTS

**5-7.1 General.**

Most foundation movements are caused by movement of the supporting soil. For this reason, it is desirable to give a brief description of these movements, although the basic theory involved is beyond the scope of this Manual. Soil deformations are caused by volume changes in the soil or by a shear failure. Slope slides and bearing failures are good examples of shear failures. Where loads are not large enough to cause shear failure, settlements may still occur as a result of volume change. The length of time and magnitude of the settlements depend upon the composition of the soil. Granular solids, such as sand, will usually undergo a relatively small volume change in a short period of time. However, cohesive soils, such as clay, can undergo large deformations, or volume changes, which may continue for years. This latter process, called consolidation, is usually confined to clays and clayey silts. Substructures that are supported directly by a cohesive soil may continue to settle for a long period of time. Consolidation usually produces vertical settlement.

**5-7.2 Types of Movements.**

For convenience, foundation movements may also be classified, somewhat arbitrarily, into the following:

a. *Lateral Movements.* Earth-retaining structures, such as abutments and retaining walls, are susceptible to lateral movements, although piers sometimes also undergo such displacements.

b. *Vertical Movements (Settlements).* Any type of substructure not founded on solid rock may be subject to settlement (fig. 5-29).

c. *Pile Settlements.* While pile settlement could be listed under lateral or vertical movements, it is mentioned separately since there is a tendency to consider piles as a panacea for all foundation problems. In addition, some of the causes of failure are peculiar to piled foundations.

d. *Rotational Movement (Tipping).* Rotation movement of substructures can be considered to be the result of unsymmetrical settlements or lateral movements. It will be discussed under the movement that is typical of the various substructures.

**5-7.3 Causes of Foundation Movements.**

The following causes of foundation movements, except as specifically noted, can produce lateral and/or vertical movements depending on the characteristics of the loads or substructures.

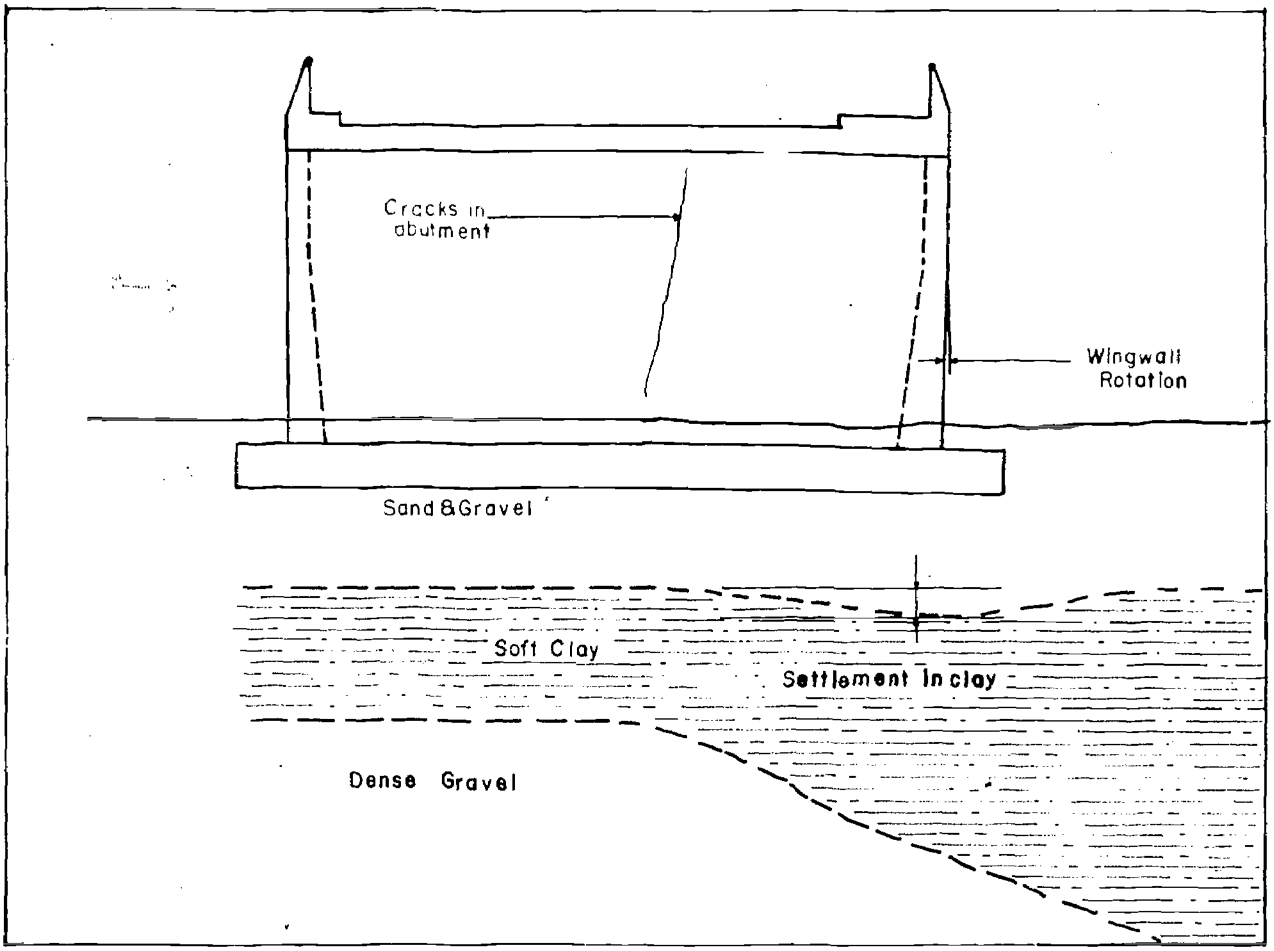



*Figure 5–29. Differential settlement under an abutment.*

a. *Slope Failure (Embankment Slides)*. These are shear failures manifested as lateral movements of hillsides, cut slopes, or embankments. Footing or embankment loads imposing shear stresses greater than the soil shear strength are common causes of slides (fig. 5–30).

b. *Bearing Failures*. Bearing failures are settlements or rotations of footings due to a shear failure in the soil beneath (fig. 5–31). When bearing failures, or slope failures, take place on an older structure, it usually indicates a change in subsurface conditions. This may endanger the security of nearby structures and foundations.

c. *Consolidation*. Serious settlement can result from consolidation action in cohesive soils. Settlement of bridge foundations may be caused by changes in the ground water conditions, the placement of additional embankments near the structure, or increases in the height of existing embankments.

d. *Seepage*. The flow of water from a point of higher head (elevation or pressure) through the soil to a point of lower head is seepage (fig. 5–32). Seepage develops a force which acts on the soil through which the water is passing. Seepage results in lateral movement of retaining walls by:

(1) An increase in weight (and lateral pressure) of the backfill because of full or partial saturation.

(2) A reduction in resistance provided by the soil in front of the structure.

e. *Water Table Variations*. Large cyclic variations in the elevation of the water table in loose granular soils may lead to a compaction of the upper strata. The effects of non-cyclic changes in the water table such as consolida-

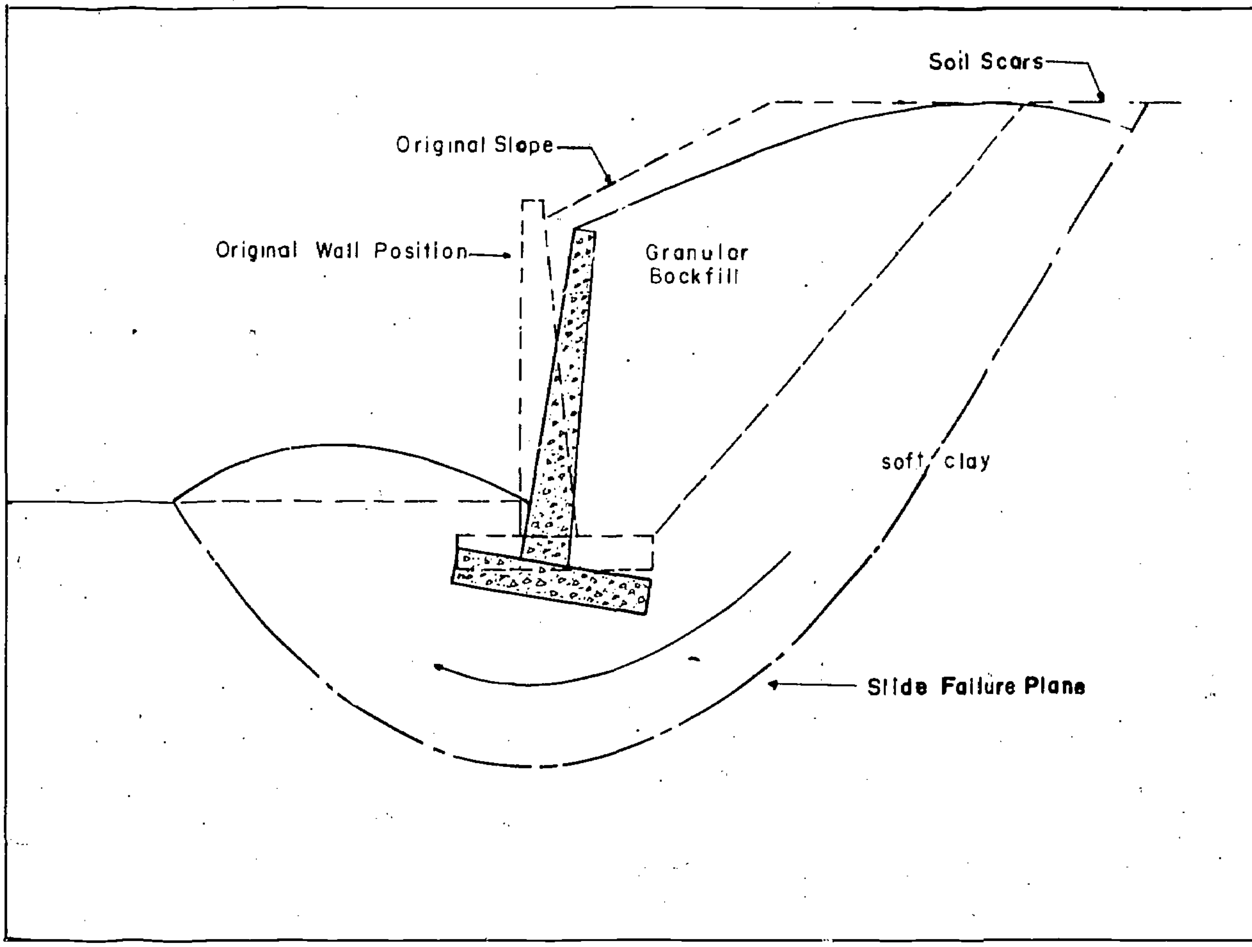



*Figure 5–30. Slide failure.*

tions, slides, and seepage were previously discussed. Changes in the water table may also change the characteristics of the soil which supports the foundation. Changes in soil characteristics may, in turn, result in the lateral movement or the settlement of the foundation.

f. *Frost Action.* Frost heave in soil is caused by the growth of ice lenses between the soil particles. Footings located above the frost line may suffer from the effects of frost heave and a loss in bearing capacity due to the subsequent softening of the soil. The vertical elements on light trestle bents may also be lifted by frost and ice actions.

g. *Expansive Soils.* Some clays, when wet, absorb water and expand, placing large horizontal pressures on any wall retaining such soil. Structures founded on expansive clay may also experience vertical soil movements (reverse settlement).

h. *Ice.* Ice can cause lateral movement in two ways. Where fine grained backfill is used in retaining structures and the water table is above the frost line, the expansion of freezing water will exert a very large force against a wall. The piers of river bridges are also subject to tremendous lateral loads when an ice jam occurs at the bridge.

i. *Thermal Forces from Superstructures.* On structures without expansion bearings, or where the expansion bearings fail to operate, thermal forces may tip the substructure units. Pavement thrust is another force that will have the same effect.

j. *Drag Forces.* Additional embankment loads or very slow consolidation of a subsurface compressible stratum will exert vertical drag forces on the bearing piles which are driven through such material. This may cause yielding or failure of the piles (fig. 5–33).

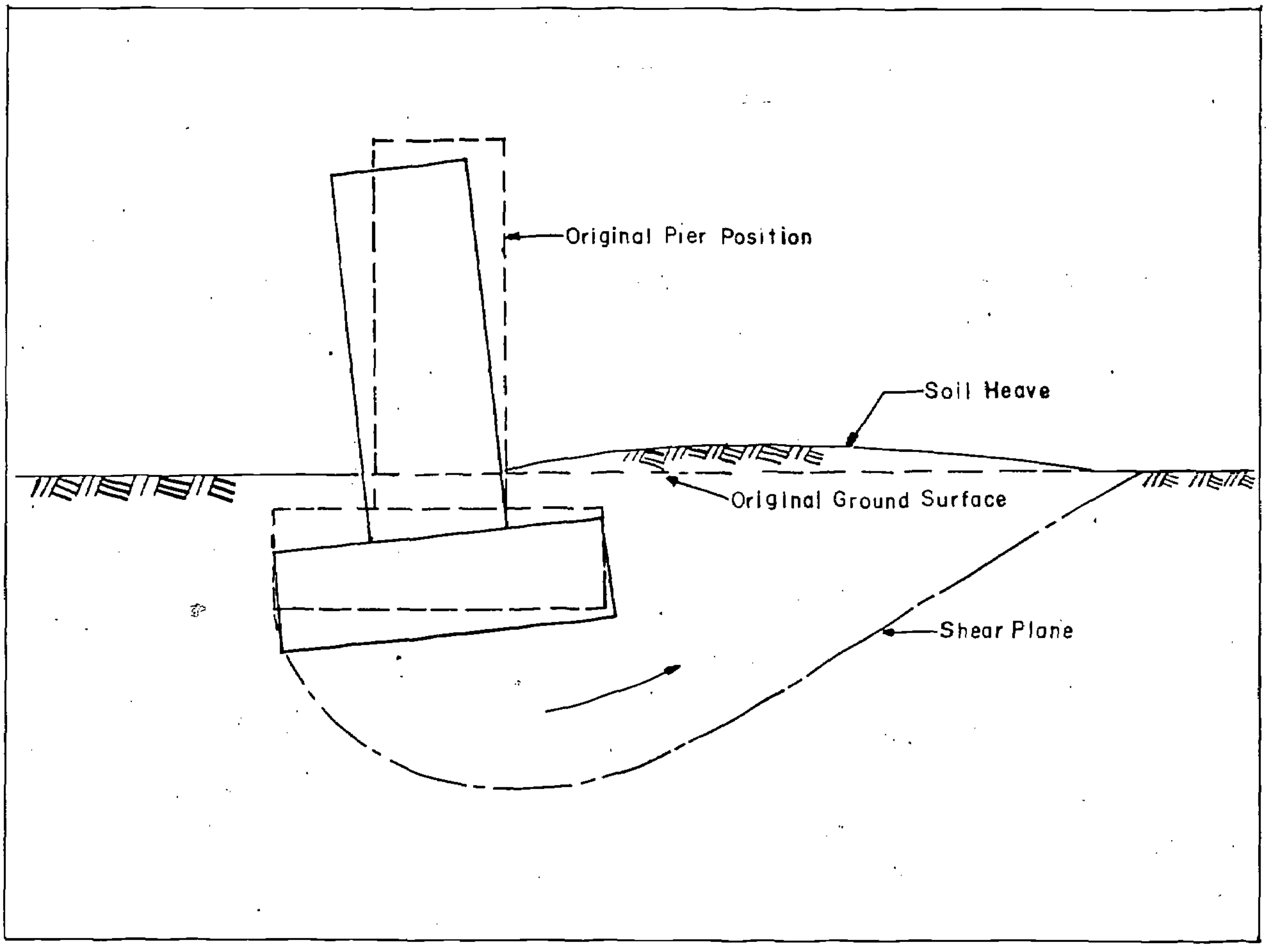



*Figure 5–31. Bearing failure.*

k. *Deterioration, Insect Attacks, and Construction Defects.* All piles may develop weaknesses leading to foundation settlements from one or more of these causes:

(1) Timber, steel, and concrete piles are subject to loss of section because of decay, rusting, and deterioration.

(2) Timber piles are vulnerable to marine borers and ship worms.

(3) Construction defects include overdriven piles, underdriven piles, failure to fill pile shells completely with concrete, or imperfect casings of a cast-in-place pile. Any of these defects will produce a weaker pile. Settlement will probably be gradual in improperly driven piles or in piles with weak or voided concrete. Piles suffering severe loss of section due to rust, spalling, chemical action, or insect infestation may fail suddenly under an unusually heavy load.

l. *Scour (Erosion).* Scour can cause extensive settlement. Since water will carry off particles of soil in suspension, a considerable hole can be formed around piers or other similar structural objects. This condition results in a greater turbulence of the water and an increased size of soil particles that can be displaced.

m. *Earth or Rock Embankments (Stockpiles).* Post-construction placement of embankments may cause instability since it will produce greater loads than were included in the original design.

### 5–7.4 Effects on Structures.

The effects of foundation movements upon a structure will vary according to the following factors:

a. *Magnitude of Movements.* All foundations undergo some settlement, even if only elastic compression of ledge or piles. All sizable foot-

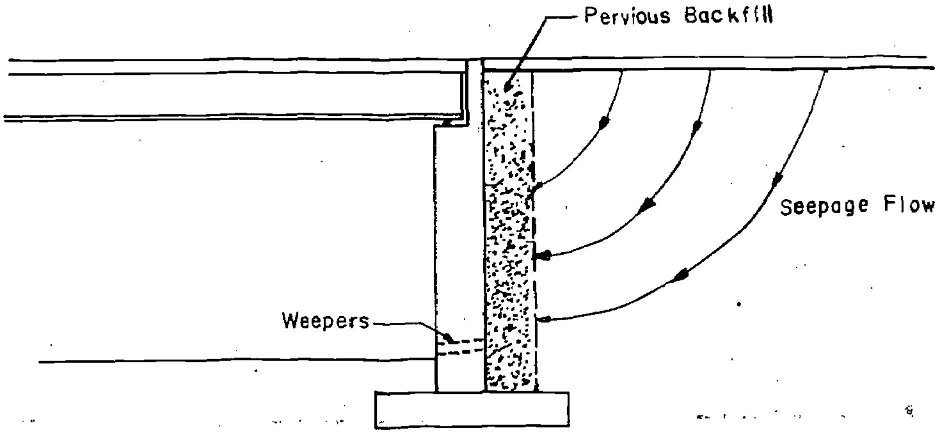



*Figure 5–32. Seepage forces at an abutment.*

ings probably will experience a minute differential settlement. However, very small foundation movements have no effect. Simple structures, and those with enough joints, will tolerate even moderate differential displacements with little difficulty other than minor cracking and the binding of end dams. Movements of large magnitudes, especially when differential, cause distress in nearly all structures (see Differential Settlement). Large movements will cause deck joints to jam; slabs to crack; bearings to shift; substructures to crack, rotate, or slide; and superstructures to crack, buckle, and, possibly, even to collapse. The larger the settlement to be accommodated within a given distance, the more structural damage can be anticipated.

b. *Types of Settlements.*

(1) *Uniform Settlement.* A uniform settlement of all the foundations of a bridge will have little effect upon the structure. Settlements of nearly one foot have been experienced by small (70-foot) single span bridges with no sign of appreciable distress.

(2) *Differential Settlement.* Differential settlements can produce serious distress in any bridge. Where the differential settlement occurs between different substructure units, the magnitude of the damage depends on the bridge type and span length. Should a differential settlement take place beneath the footings of the same substructure, damage can vary from an opening of the vertical expansion joints between the wing wall and the abutment, to severe tipping and cracking of walls or other members. Scour, as shown in figures 5–34 and 5–35, can cause complete failure.

c. *Types of Structure.*

(1) *Simple (Determinate).* As mentioned above, the strength of a simple, or determinate,

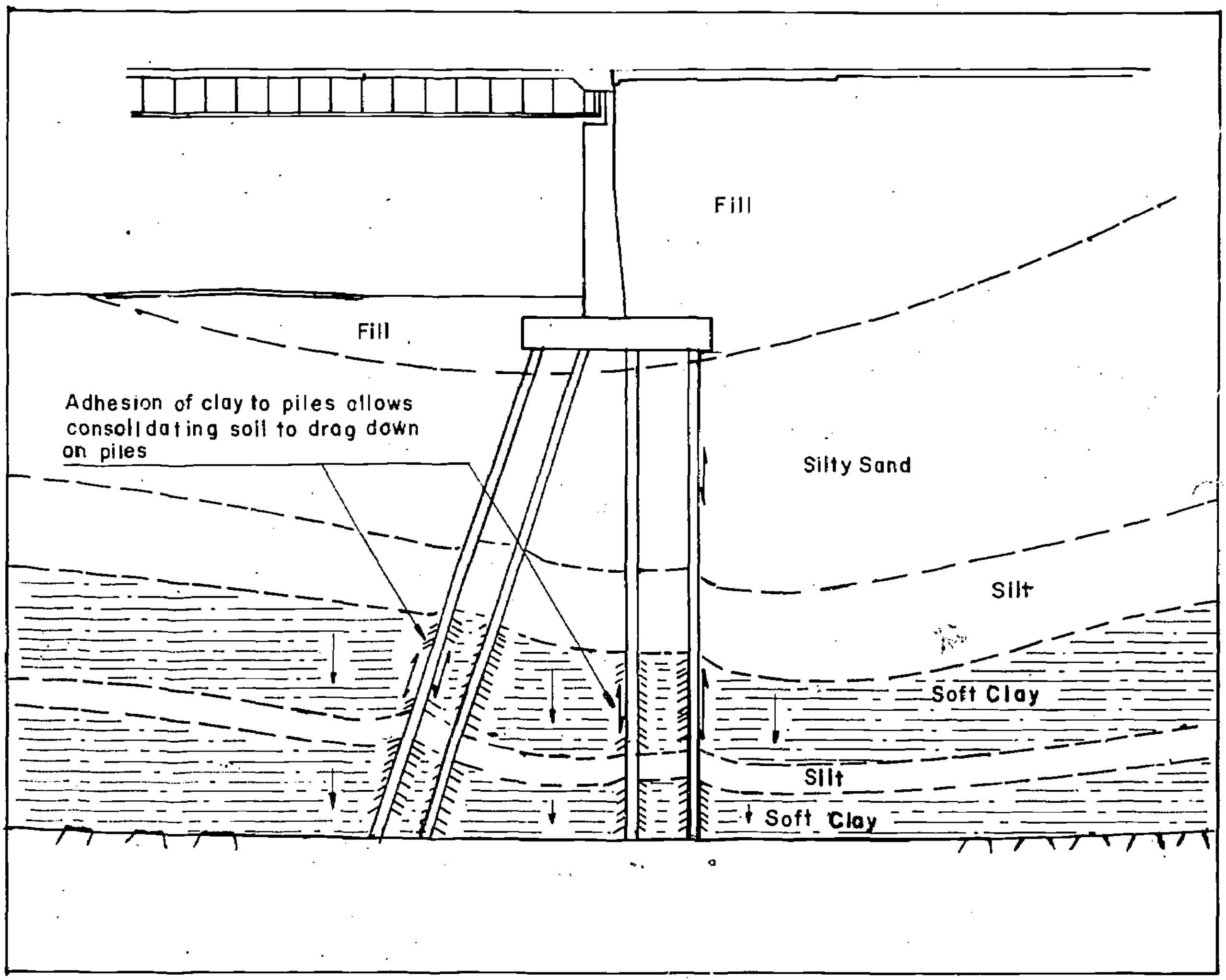



*Figure 5–33. Drag forces on piles.*

structure usually is not affected by movements unless they are quite large. There are usually enough joints to permit the movements without major damage to the basic integrity of the structure. At most, some finger joints or bearings may require resetting, or beam supports may need shimming. However, pile bent or trestle bridges are very vulnerable since a large settlement or movement of a bent could cause the superstructure to fall off a narrow bridge seat, leading to the loss of the bridge spans.

(2) *Indeterminate Bridges.* An indeterminate bridge is seriously affected by differential movements, since such movements at supports will redistribute the loads, possibly causing large overstresses. For example, a fixed-ended arch could be severely damaged if a foundation rotates. Most continuous bridges have fewer joints than simple span bridges. These bridges are very likely to be damaged if subjected to displacements which are greater in magnitude, or different in direction, from those that were considered in the original designs.

### 5–7.5 What to Look for During Inspection.

Foundation movements may often be detected by first looking for deviations from the proper geometry of the bridge. With the exception of curved structures, haunched members, and steeply inclined bridges, members and lines should usually be either parallel or perpendicular to each other. While not always practical, especially for bridges spanning large bodies of water or for those located in urban industrial areas, careful observation of the overall structure for lines that seem incongruous with the rest of the bridge is a good starting point. For a more detailed inspection, the following methods are often useful:

*Figure 5–34. Pier settlement due to scour. Note pier and deck cracking.*

a. *Check the Alignment.* Any abrupt change or kink in the alignment of the bridge may indicate a lateral movement of a pier or of bearings. Older bridges are particularly vulnerable to ice pressures which can cause structural misalignment.

b. *Sight Along Railings.* A sudden dip in the rail line is often the result of settlement of a pier or abutment.

c. *Run Profile Levels Along the Centerline and/or the Gutter Lines.* This inspection technique will not only help to establish the existence of any settlement, but will also identify any differential settlements across the roadway. Normally this kind of inspection technique will be employed only for large bridges or where information concerning the extent and character of differential settlement movement is required.

d. *Check Piers, Pile Bents, and Abutment Faces for Plumbness with a Transit.* This inspection method provides an excellent check for the simpler techniques of plumbness determination. An out-of-plumb pier in either direction usually signifies foundation movement; it may also indicate a superstructure displacement. For small bridges and for preliminary checks, the use of a plumb bob is an adequate means for determining plumbness.

e. *Observe the Inclination of Expansion Rockers or Roller Movements.* Rocker inclinations inconsistent with seasonal weather conditions may be a sign of foundation or superstructure movement. Of course, this condition may also indicate that the expansion rockers were set improperly. Out-of-plumb hangers on cantilevered structures are another indication of foundation shifting.

f. *Observe Expansion Joints at Abutments and Walls.* Observe the expansion joints for signs of opening or rotating. These conditions may indicate the movement of subsurface soils or a bearing failure under one of the footings.

g. *Check Deck Joints and Finger Dams.* Abnormally large or small openings, elevation differential, or jamming of the finger dams can be caused by substructure movements. Soil movements under the approach fills are also frequent occurrences.

h. *Observe Slabs, Walls, and Members.* Cracks, buckling, and other serious distortions should be noted. Bracing, as well as the main supporting sections, should be scrutinized for distortion.

i. *Check Backwalls and Beam Ends.* Check the backwalls for cracking which may be caused by either abutment rotation, sliding, or pavement thrust. Check for beam ends which are bearing against the backwall. This condition is a sign of horizontal movement of the abutment.

j. *Observe Fill and Excavation Slopes.* Slide scarps, fresh sloughs, and seepage are indications of past or imminent soil movement.

k. *Scour* (See Waterways, Section 5–26).

l. *Unbalanced Post-Construction Embankment or Fills.* Embankments or fills should be checked for balance and positioning. Unbalanced embankments or fills can cause a variety of soil movements which may impair the structural integrity of the bridge.

m. *Underwater Investigation of All Piling and Pile Bents.* Underwater investigation of piling and pile bents should be undertaken periodically. Check all timber piles for insect attack and deterioration. Examine steel piles well

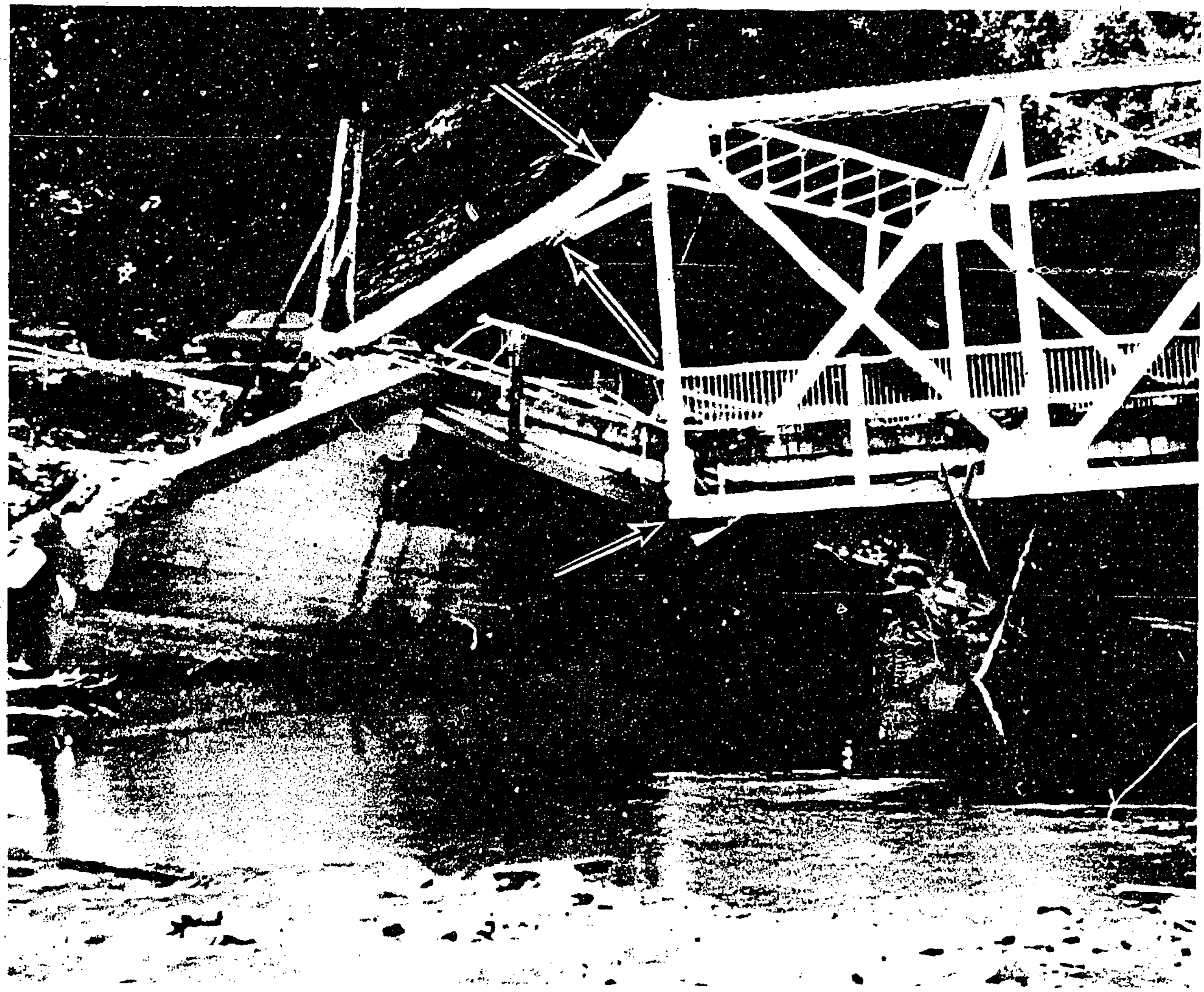


*Figure 5-35. Abutment failure due to scour. Note buckling of end posts and bottom chord, and failure of portal knee brace connection.*

below the water surface. Steel piles protected in the splash zone can rust between the concrete jacket and the mud line. Examine pre-stressed piles below water for cracking or splitting.

## Section 8. ABUTMENTS

### 5-8.1 General.

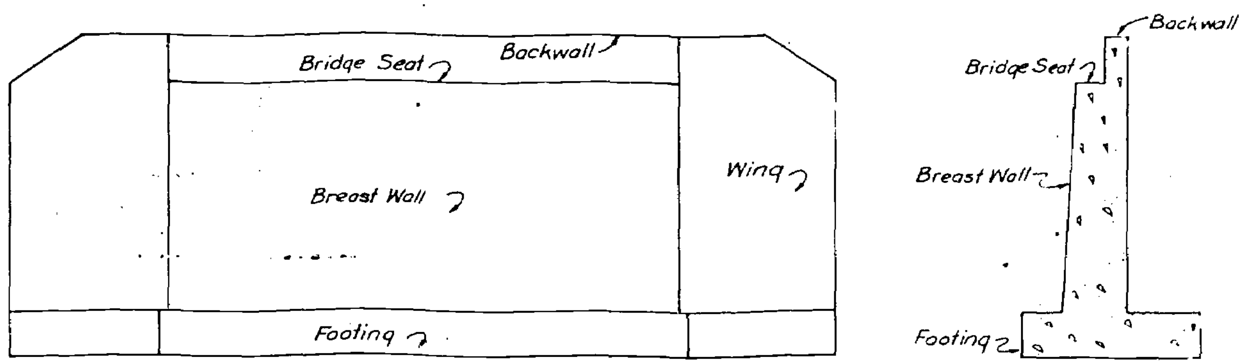
The term "abutment" is usually applied to the substructure units at the ends of bridges. Abutments are classified according to their locations as full height (shoulder), semi-stub, stub, or spill-through abutments. Figures 5-36, 5-37, and 5-38 show different types of abutments.

a. *Function.* Abutments provide end support for the bridge and retain the approach embankment.

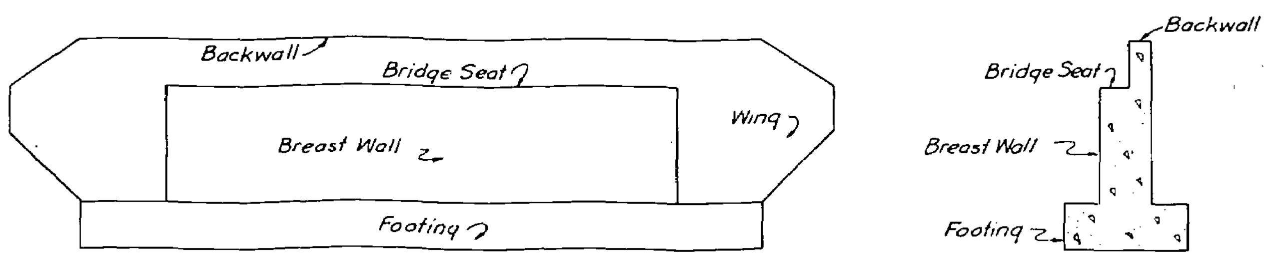
b. *Construction.* Abutments may be constructed of plain concrete, reinforced concrete, stone masonry, or a combination of concrete and stone masonry. Plain concrete and stone masonry abutments are usually gravity structures, while reinforced concrete abutments are mostly cantilever or counterfort types.

### 5-8.2 What to Look for During Inspection.

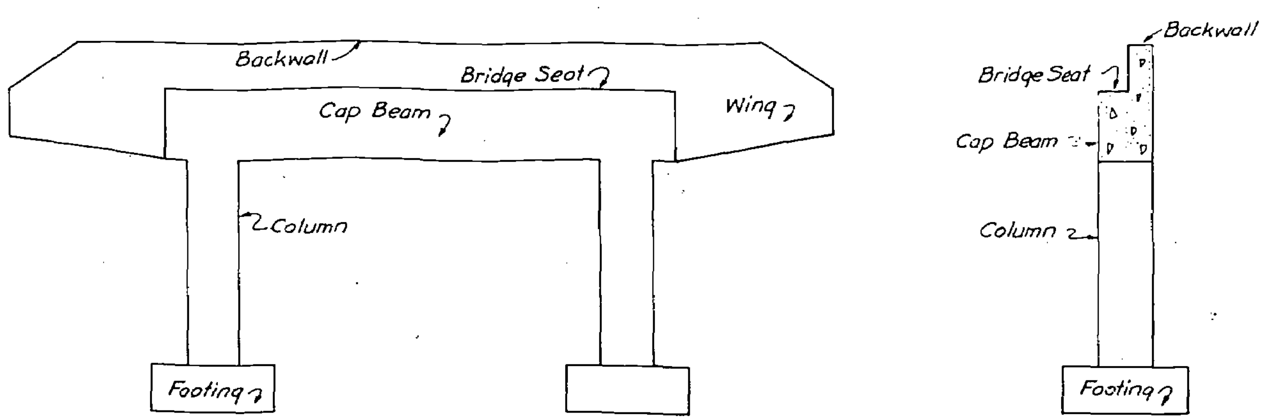
a. Check for scour or erosion around the abutment, and for evidence of any movement (sliding, rotation, etc.), or settlement. Open cracks between adjoining wing walls or in the




FULL HEIGHT ABUTMENT




STUB ABUTMENT




OPEN ABUTMENT

*Figure 5-36. Types of abutments.*

abutment stem, off centered bearings, or inadequate or abnormal clearances between the back wall and the end beams are indications of probable movement (fig. 5–39).

b. Determine whether drains and weepholes are clear and functioning properly. Seepage of water through joints and cracks may indicate accumulation of water behind the abutment. Report any frozen or plugged weep holes. Mounds of earth immediately adjacent to weepers may indicate the presence of burrowing animals.

c. Check bearing seats for cracking and spalling, especially near the edges. This is particularly critical where concrete beams bear directly on the abutment. Check bearing seats for presence of debris and standing water.

d. Check for deteriorating concrete in areas that are exposed to roadway drainage. This is especially important in areas where deicing chemicals are used.

e. Check backwalls for cracking and possible movement. Check particularly the construction joint between the backwall and the abutment.

f. Check stone masonry for mortar cracks, vegetation, water seepage through the cracks, loose or missing stones, weathering, and spalled or split blocks.

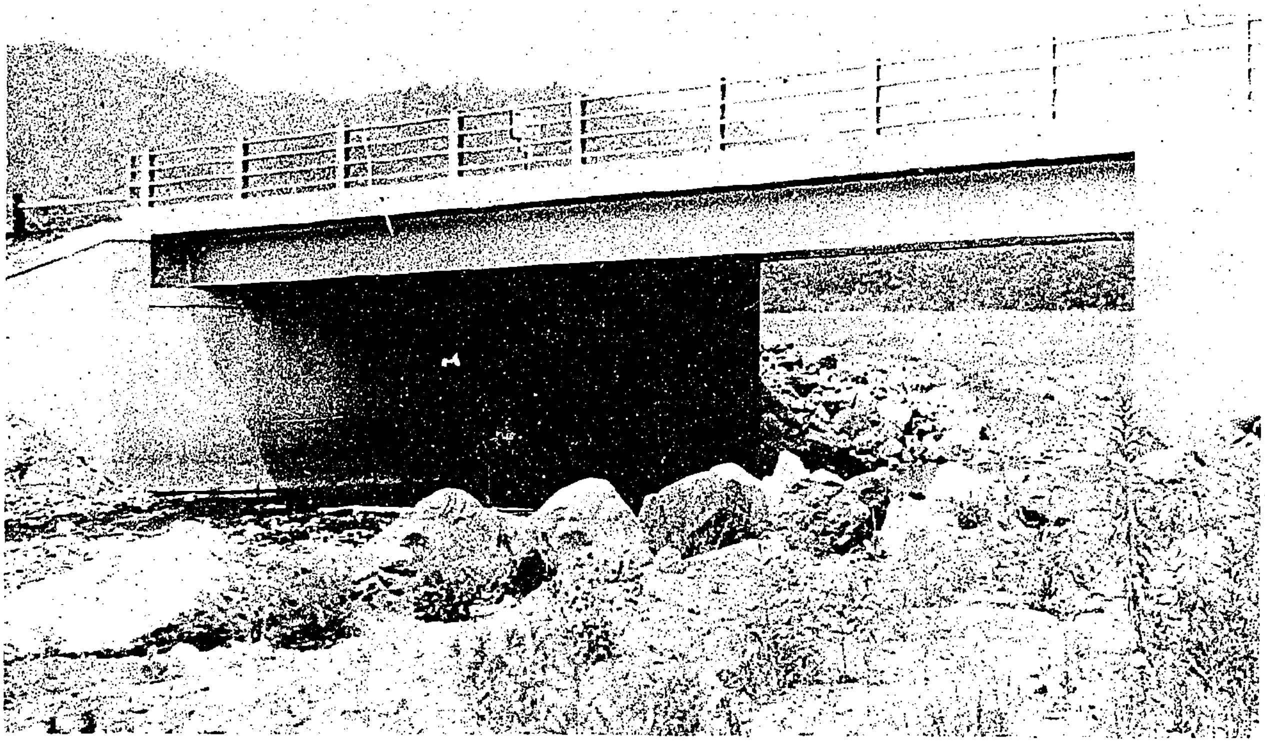


*Figure 5–37. Full-height concrete abutment.*

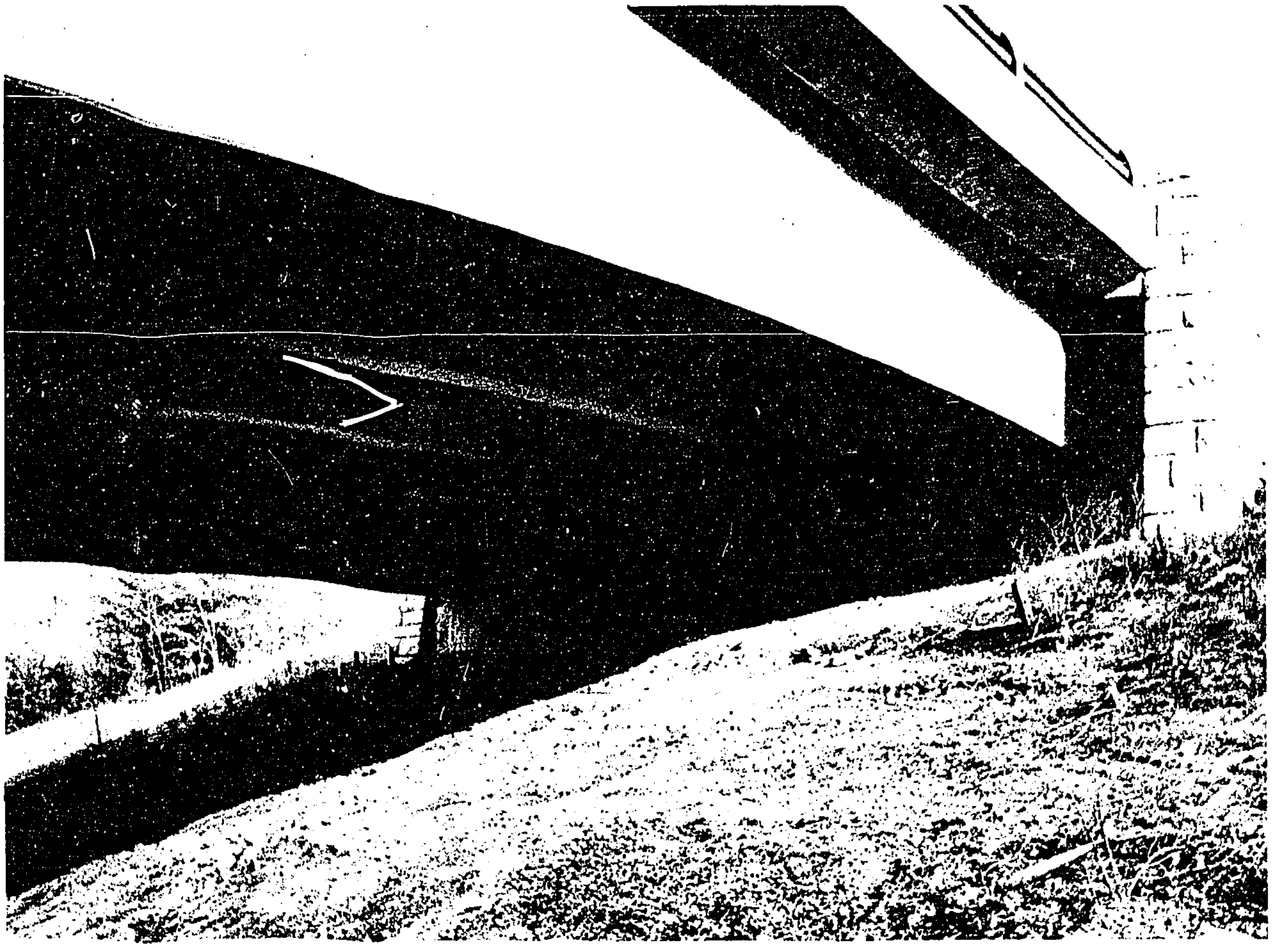


*Figure 5–38. Concrete and stone masonry stub abutment.*

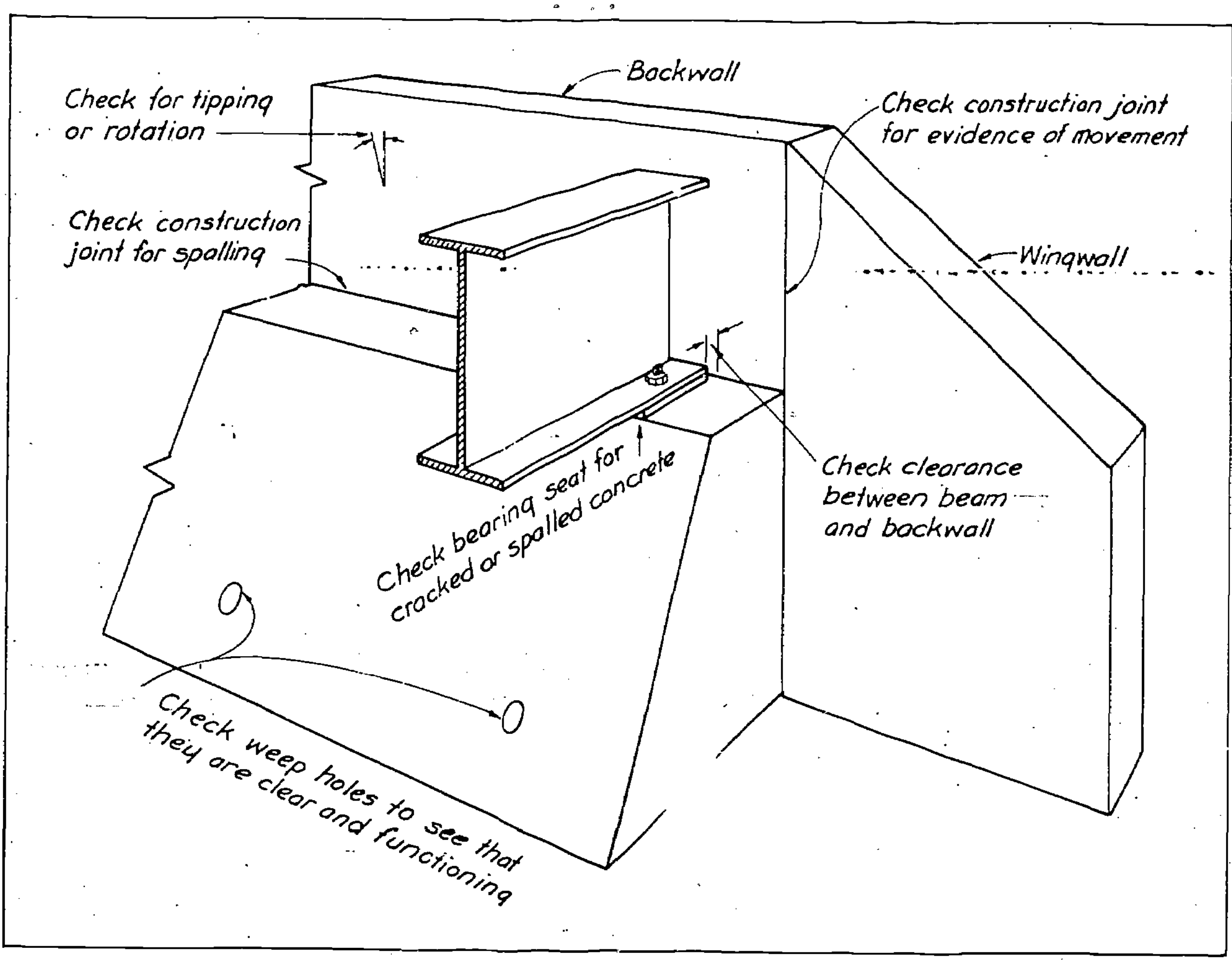



*Figure 5–39. Abutment checklist items.*

## Section 9. RETAINING WALLS

### 5–9.1 General.

Retaining walls are designed to maintain a difference in the elevation between the ground surfaces on the two sides of the wall. The earth whose surface is at the higher elevation is commonly called "backfill". The retaining wall is a modification of the abutment since it is not required to carry any vertical loads. The absence of the vertical superstructure load usually also requires a wider footing to resist the large net overturning moment carried by a retaining wall.

a. *Wing walls.* Wing walls are the walls on the sides of an abutment which enclose the approach fill. Wings are classified as straight, flared, or U wings, depending upon their orientation. Straight wing walls are extensions of the abutment wall, flared wing walls form an acute angle with the axis of the bridge roadway, and U wings are parallel to the roadway. The granite-faced walls in figure 5–38 are U wings while flared wings are shown in figure 5–37.

b. *Crib walls.* Crib walls are composed of interlocking precast or prefabricated members. The crib resists overturning by tensile forces in the anchoring pieces, or deadmen, which extend from the surface backward into the fill. Crib walls are made of:

(1) *Timber.* Old railroad structures often used crib walls made of railroad ties.

(2) *Precast concrete.*

(3) *Steel.* Steel crib walls are actually corrugated bin-type retaining walls.

### 5–9.2 What to Look for During Inspections.

Inspection of most retaining walls should be similar to that of an abutment. Crib walls are subject to the same types of deterioration as other structures of wood, concrete, and steel.

a. Settlement of the soil under the embankment will lead to distortion and possible damage to a crib wall. If sufficient movement occurs, the wall may fail.

b. Timber cribs may decay or be attacked by termites. However, the creosote treatment is usually very effective in protecting the wood.

c. Concrete cribs are subject to chipping and spalling. In addition, the locking keys or flanges at the ends of the crib pieces are sometimes broken off by vandals or inadvertently damaged by casual passers-by.

## *Section 10. PIERS AND BENTS*

### 5–10.1 General.

Piers and bents provide intermediate support to the bridge superstructures (figs. 5–40 and 5–41). They may be composed of plain or reinforced concrete, stone masonry, steel, timber, or a combination of these materials. Figure 5–42 exhibits the different types of piers.

### 5–10.2 What to Look for During Inspection.

a. Check for erosion or undermining of the foundation by scour, and for exposed piles (figure 5–43). Check for evidence of tilt or settlement. (See the discussion of "Foundations" in Section 5–7.)

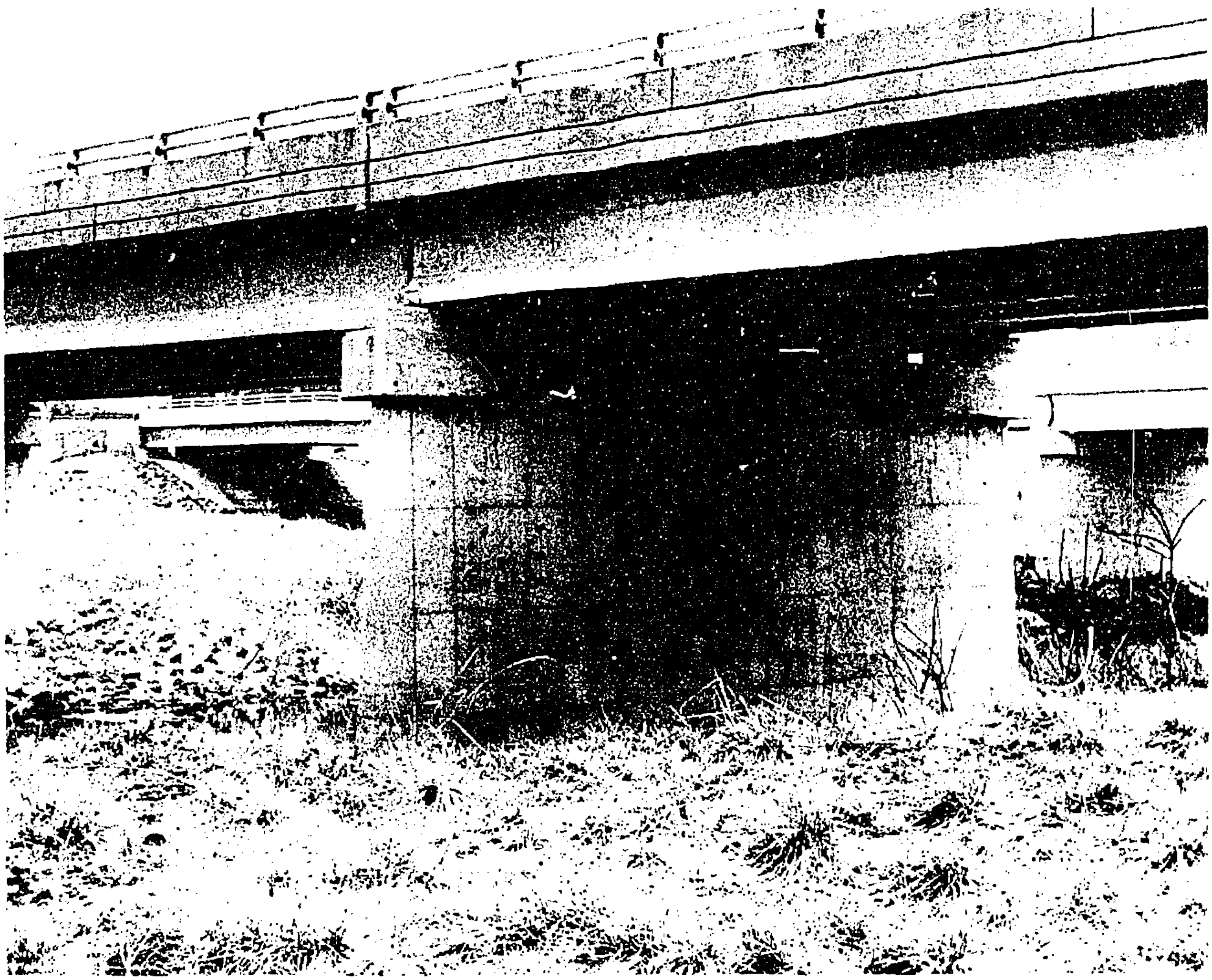


*Figure 5–40. Solid concrete pier.*

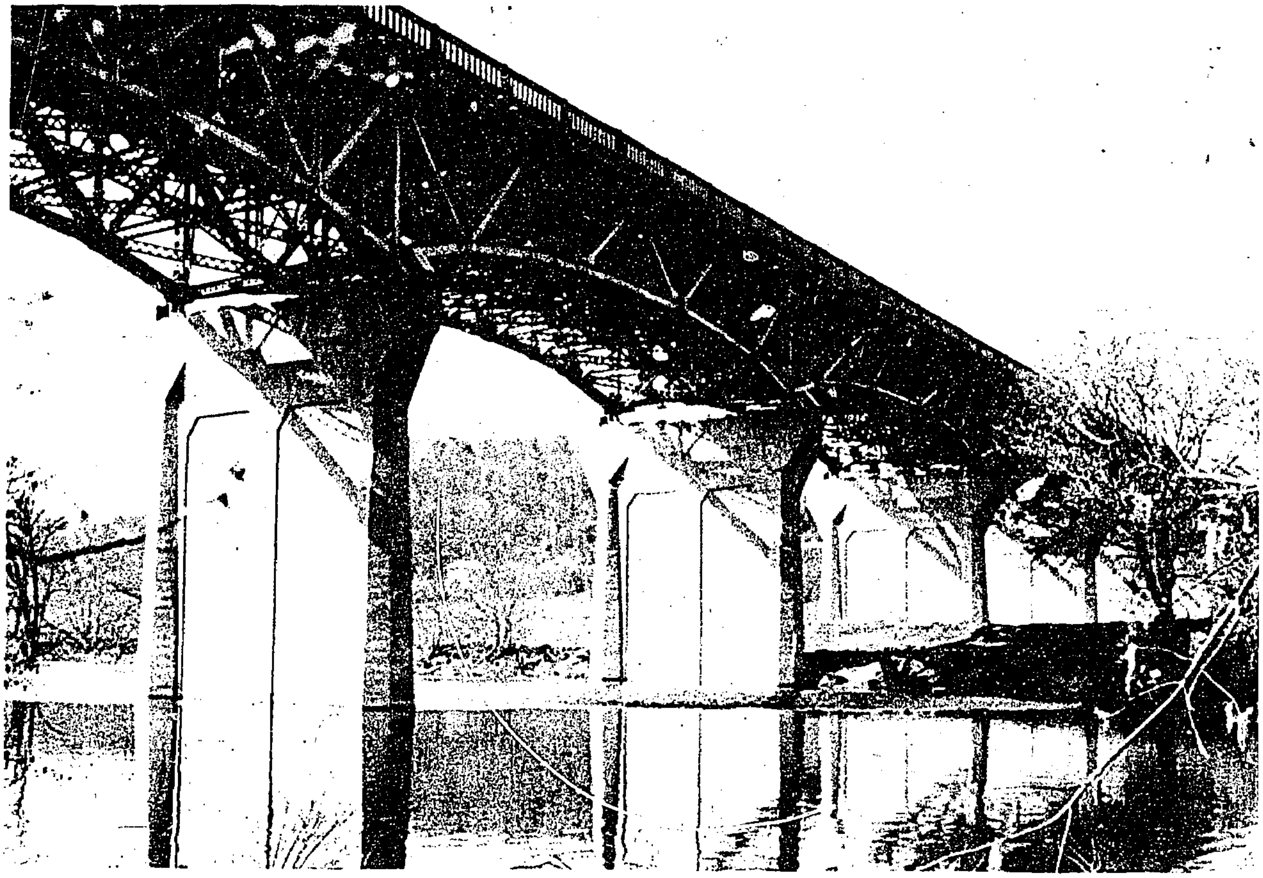


*Figure 5–41. Column piers with solid web walls.*

b. Check for disintegration of the concrete, especially in the splash zone, at the water line, at the ground line, and wherever concrete is exposed to roadway drainage (fig. 5–44).

c. Check the pier columns and the pier caps for cracks.

d. Check the bearing seats for cracking and spalling.

e. Check stone masonry piers and bents for mortar cracks, water and vegetation in the cracks, and for spalled, split, loose, or missing stones.

f. Check steel piers and bents for corrosion (rust), especially at joints and splices. Bolt-heads, rivet-heads, and nuts are very vulnerable to rust, especially if located underwater or in the base of a column.

g. Examine grout pads and pedestals for cracks, spalls or deterioration.

h. Examine steel piles both in the splash zone and below water surface.

i. Investigate any significant changes in clearance for pier movement.

j. Check all pier and bent members for structural damage caused by collision or overstress.

k. Where a steel cap girder and continuous longitudinal beams are framed together, check the top flanges, welds, and webs for cracking.

l. Observe and determine whether unusual movement occurs in any of the bent members during passage of heavy loads.

m. Where rocker bents (fig. 5–45) are designed to rotate freely on pins and bearings, check to see that such movement is not restrained. Restraint can be caused by severe corrosion or the presence of foreign particles.

n. Determine whether any earth or rock fills have been piled against piers causing loads not provided for in the original design and producing unstable conditions.

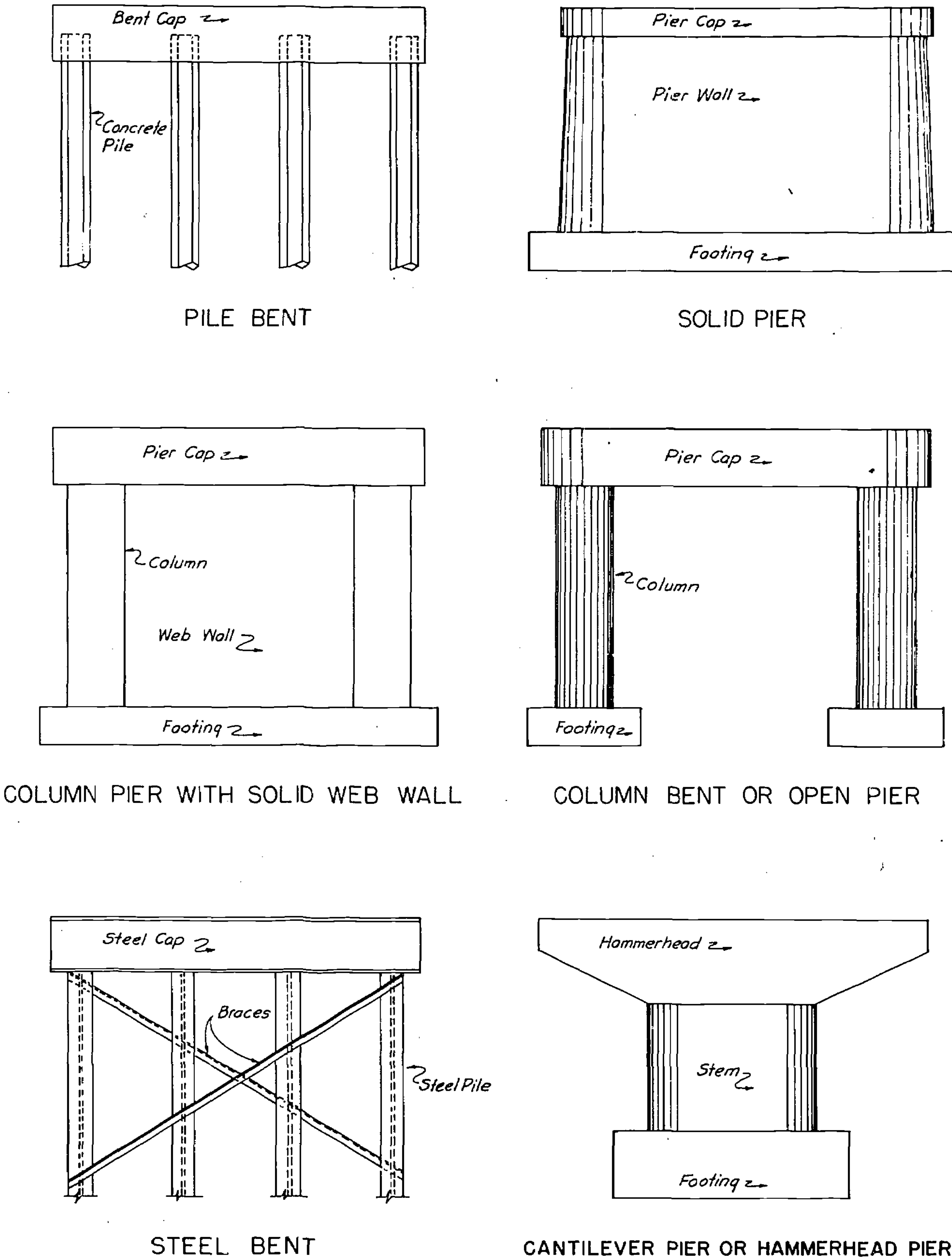



*Figure 5-42. Types of piers.*

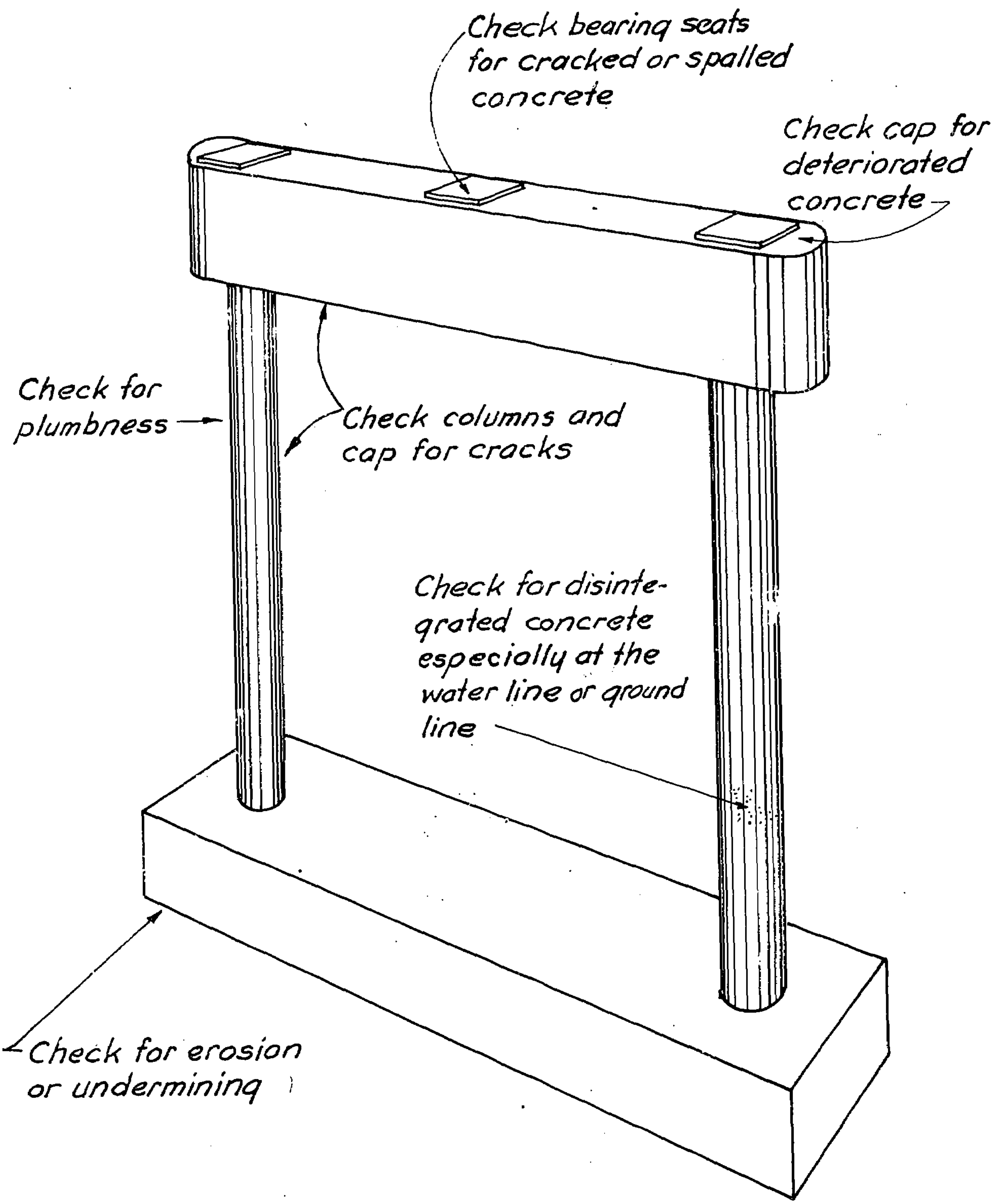



*Figure 5–43. Concrete pier and bent checklist items.*

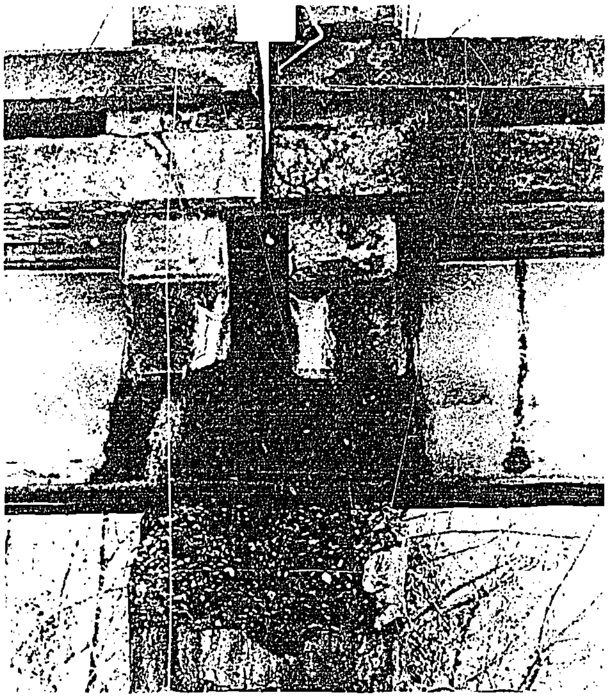


*Figure 5–44. Steel beams on concrete pier cap. Note disintegration of pier cap and deck brackets, exposure of reinforcement and corrosion of steel.*



### 5–11.1 General.

Pile bents are transverse structural frameworks composed of piles and pile caps (fig. 5–47). The cap distributes the superstructure load to the piles and ensures that the piles act together.

a. *Function.* Pile bents function as abutments or piers. When used as abutments the piles are usually completely below ground and the cap is cast integrally with the deck slab.

b. *Construction.* Pile bents may consist of concrete, timber, or steel piles.

### 5–11.2 What to Look for During Inspection.

a. *Concrete.* Check for the same items as discussed in Section 5–10, Piers and Bents.

b. *Timber.*

(1) Check for decay in the piles, caps, and bracing (fig. 5–47). The presence of decay may be determined by tapping with a hammer or by test boring the timber. Check particularly at

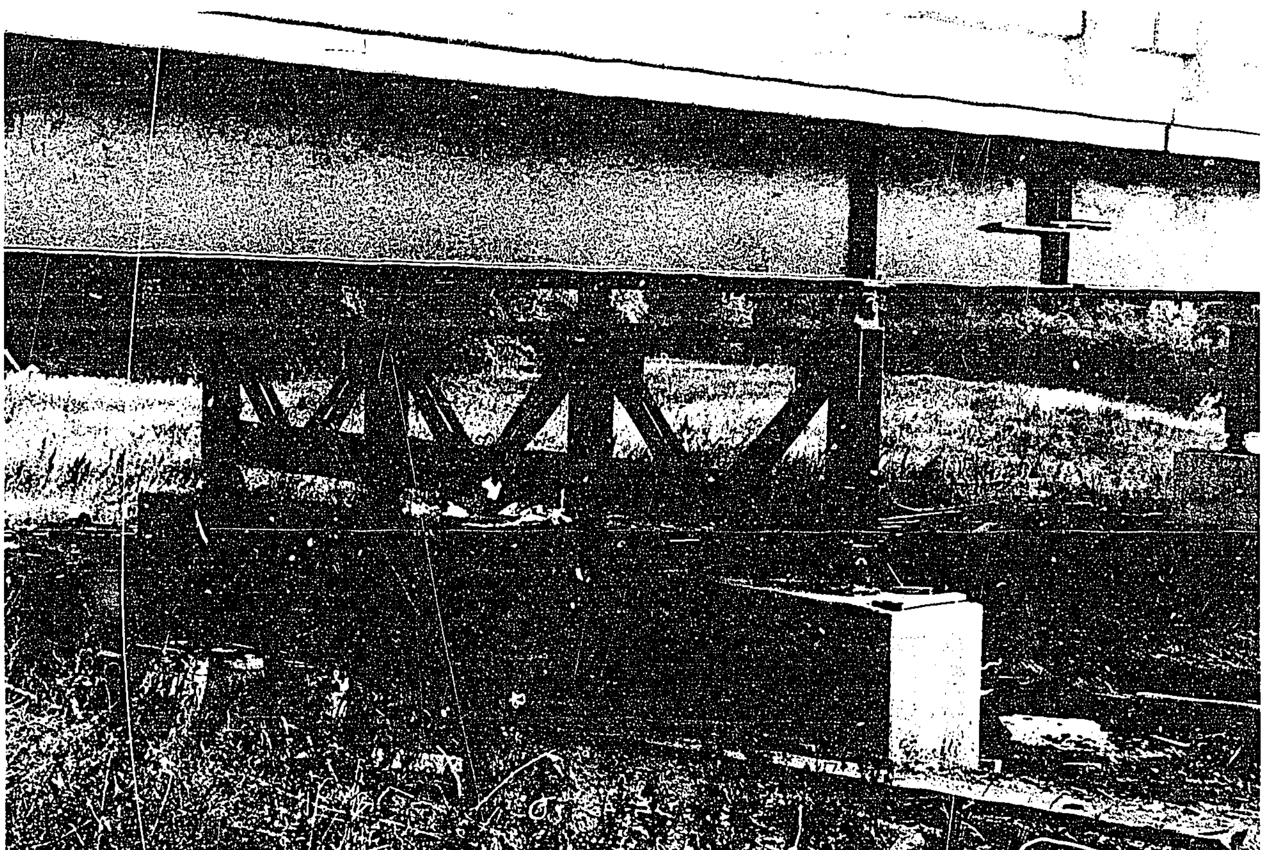


*Figure 5–45. Rocker bent.*

the ground line, or water line, and at joints and splices, since decay usually begins in these areas.

(2) Check splices and connections for tightness and for loose bolts.

(3) Check the condition of the cap at those points where the beams bear directly upon it, and at those points where the cap bears directly upon the piles. Note particularly any splitting or crushing of the timber in these areas.

(4) Observe caps that are under heavy loads for excessive deflection.

(5) Check for rotted or damaged timbers in the backwalls of end bents (abutments), especially where such conditions would allow earth to spill upon the caps or stringers. Approach fill settlement at end bents may expose short sections of piling to additional corrosion or deterioration.

(6) In marine environments, check structures for the presence of marine borers and shipworms.

(7) Check timber piles in salt water to determine damage caused by marine borers.

(8) Check timber footing piles in salt water exposed by scour below the mud line for damage caused by marine borers.

(9) Check timber piles in salt water at checks in the wood, bolt holes, daps or other connections for damage by marine borers.

c. *Steel.*

(1) Check the pile bents for the presence of rust, especially at the ground level line. Use a chipping hammer, if necessary, to determine the extent of rust. Over water crossings, check the splash zone (2 feet above high tide or mean water level) and the submerged part of the piles for indications of rust.

(2) Check for debris around the pile bases. Debris will retain moisture and promote rust.

(3) Check the steel caps for rotation due to eccentric connections.

(4) Check the bracing for broken connections and loose rivets or bolts.

(5) Check condition of web stiffeners.

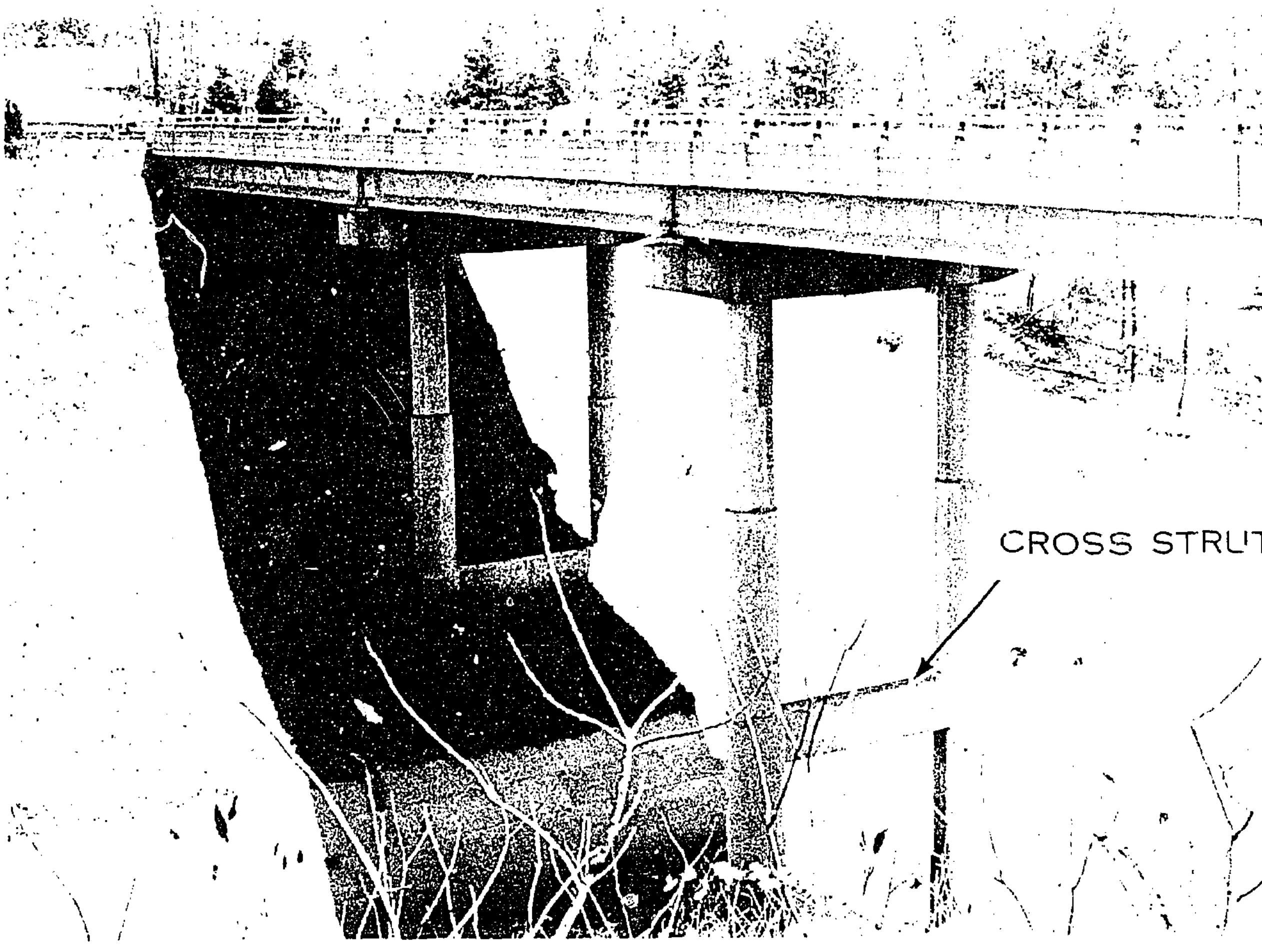



*Figure 5–46. Two column bent with cross struts.*

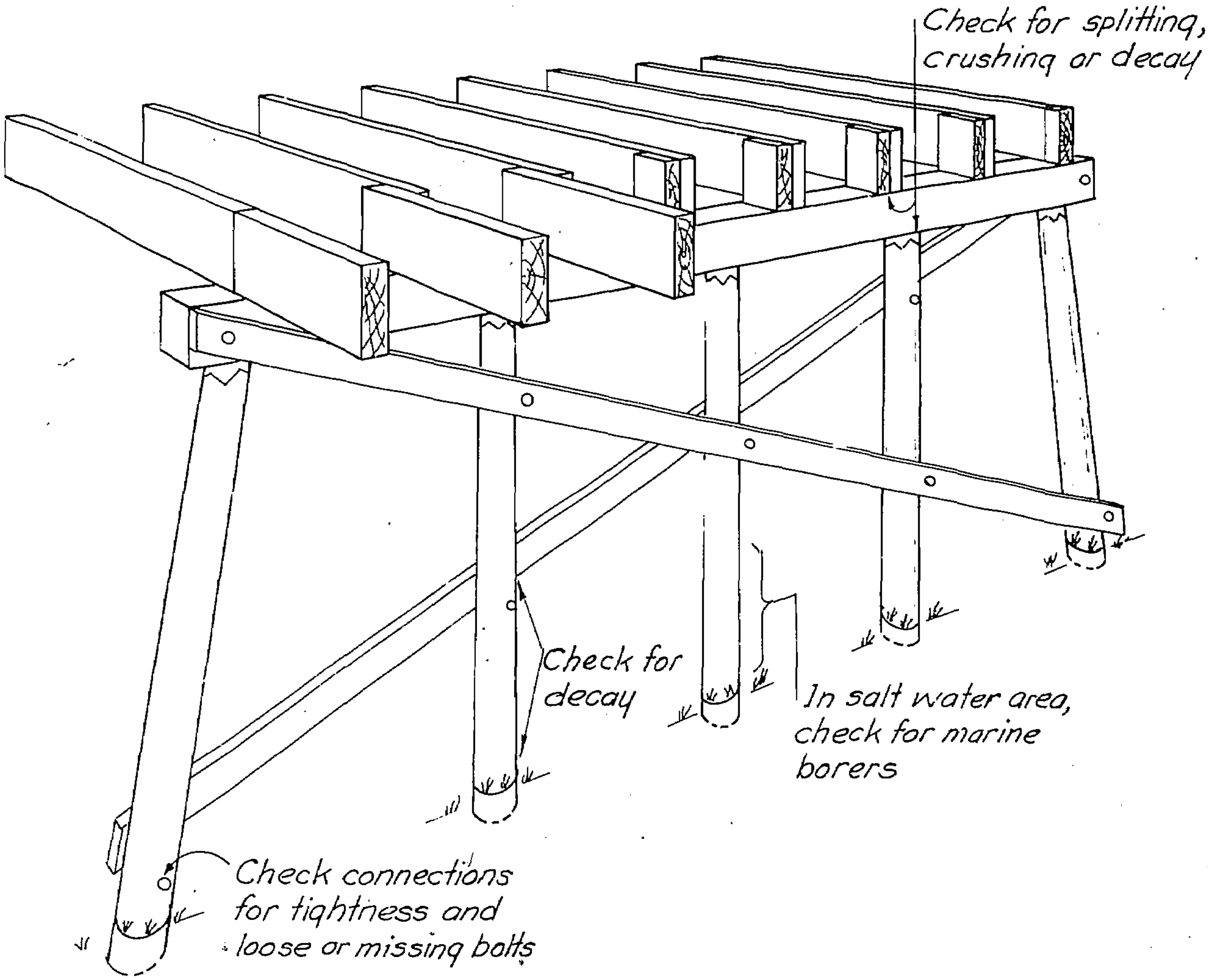



*Figure 5–47. Timber bent checklist items.*

## Section 12. CONCRETE BEAMS AND GIRDERS

### 5–12.1 General.

Concrete beams and girders transfer deck loads to the substructures. The most common concrete bridges are the slab, T-beam (fig. 5–48), I-beam, and box girder types. Box beams (fig. 5–49) and voided units are special types of the slab. The concrete slab serves as the floor of the bridge as well as the top flange of the beams. The beams and deck may be cast as a single monolithic section or composed of individual units, tied together by dowels, diaphragms, and end beams. The beams may be either conventionally reinforced or prestressed; precast or cast-in-place.

### 5–12.2 What to Look for During Inspection.

a. *All Beams.*

(1) Check for spalling concrete, giving special attention to points of bearing where friction from thermal movement and high edge pressure may cause spalling (fig. 5–50).

(2) Check for diagonal cracking, especially near the supports. The presence of diagonal cracks on the side of the beam may indicate incipient shear failure. This is particularly important on the older prestressed bridges. Cantilever box girder bridges, whether of prestressed or reinforced concrete, utilize a shiplapped joint in which the suspended span rests upon bearings located on the anchor span. Figure 5–51

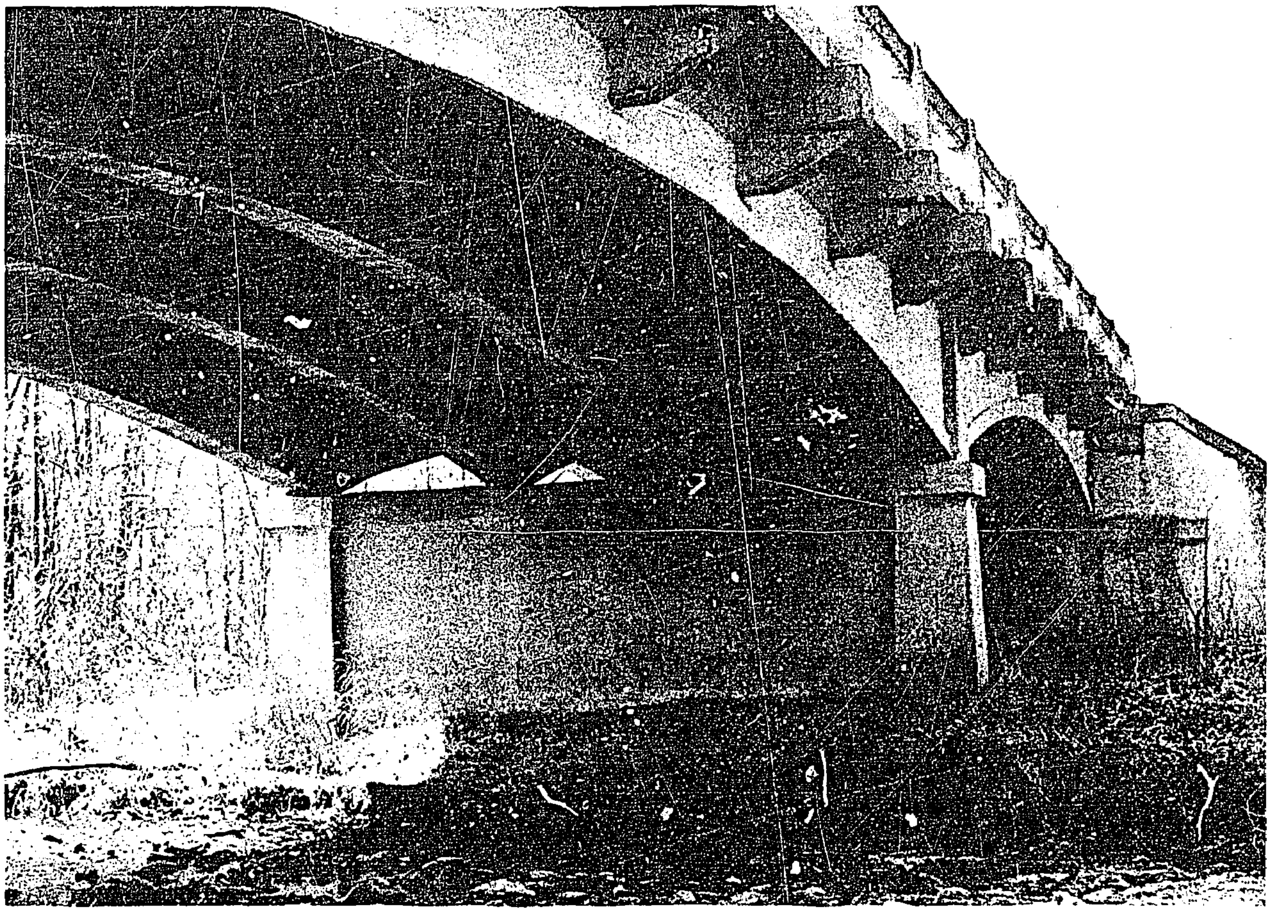


*Figure 5–48. Continuous concrete T-beam bridge.*

illustrates such a joint. The shiplap cantilevers with re-entrant corners should be inspected very carefully for signs of cracking or other deterioration.

(3) Check for flexure (vertical) cracks or disintegration of the concrete, especially in the area of the tension steel. Discoloration of the concrete surface may be an indication of concrete deterioration or the corrosion of the reinforcing steel. In severe cases, the reinforcing steel may become exposed.

(4) Observe areas that are exposed to roadway drainage for disintegrating concrete.

(5) Check for damage caused by collision or fire.

(6) Note any excessive vibration or deflection.

b. *Box Girders.*

(1) Examines the inside of box girders for cracks and to see that the drains are open and functioning properly.

(2) Check the soffit of the lower slab and the outside face of the girders for excessive cracking.

(3) Check diaphragms for cracks.

(4) Examine the underside of the slab and top flange for scaling, spalling, and cracking as described in Section 20 of this Chapter.

(5) Note any offset at the hinges which might indicate problems with the hinge bearing. An abnormal offset should be investigated further to determine the cause and the severity of the condition.

c. *Prestressed Concrete Bridges.*

(1) Check for longitudinal cracks on all flange surfaces. This may occur on older prestressed bridges where insufficient stirrups were provided.

(2) Examine the alignment of prestressed beams.

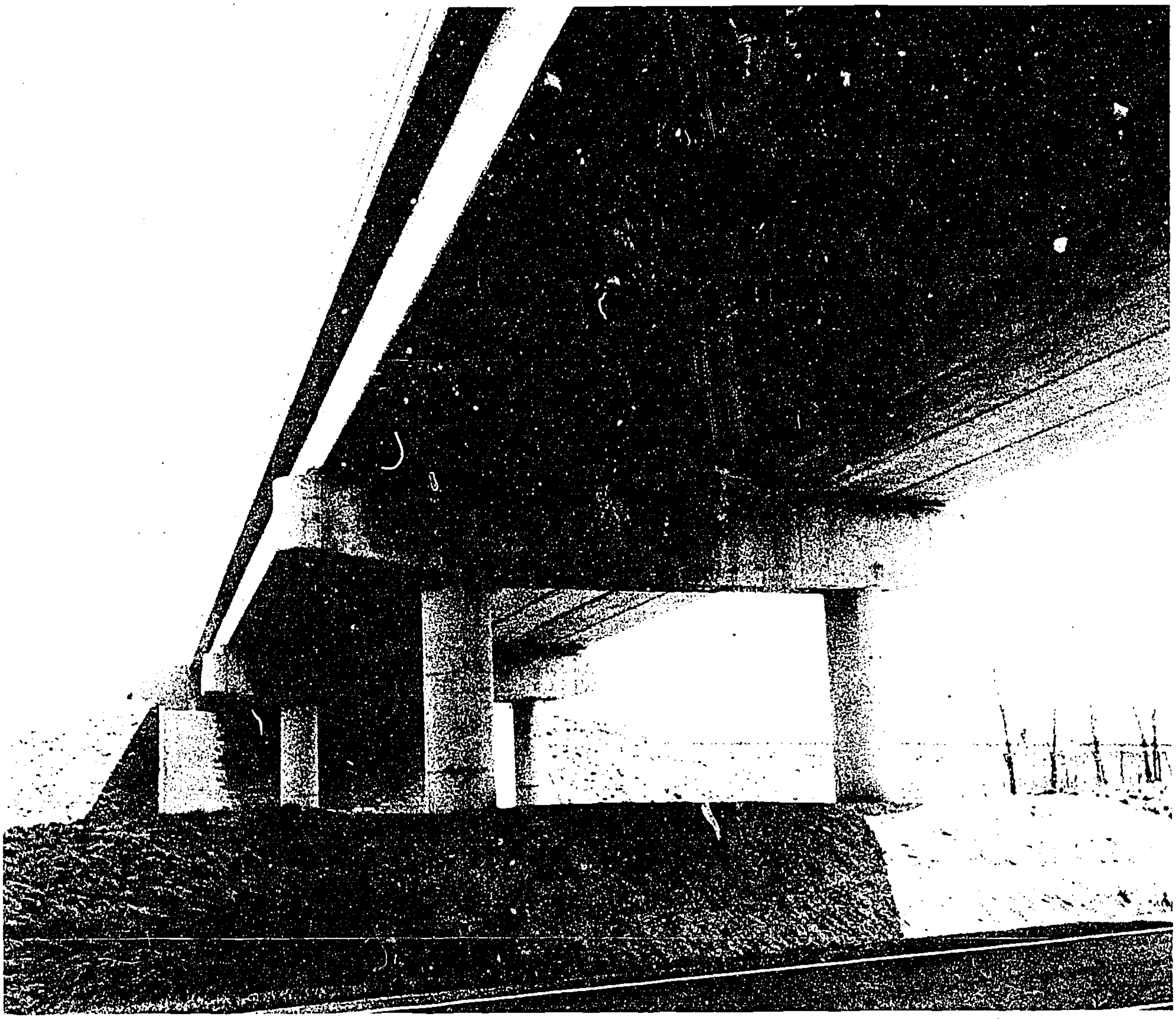


*Figure 5–49. Prestressed concrete box beam bridge.*

(3) Check for cracking and spalling in the area around the bearings and at the cast-in-place diaphragms where differential creep and humping of the beams may have some ill effects. On pretensioned deck units, either box beams or voided units, check the underside during the passage of traffic to see whether any unit is acting independently of the others.

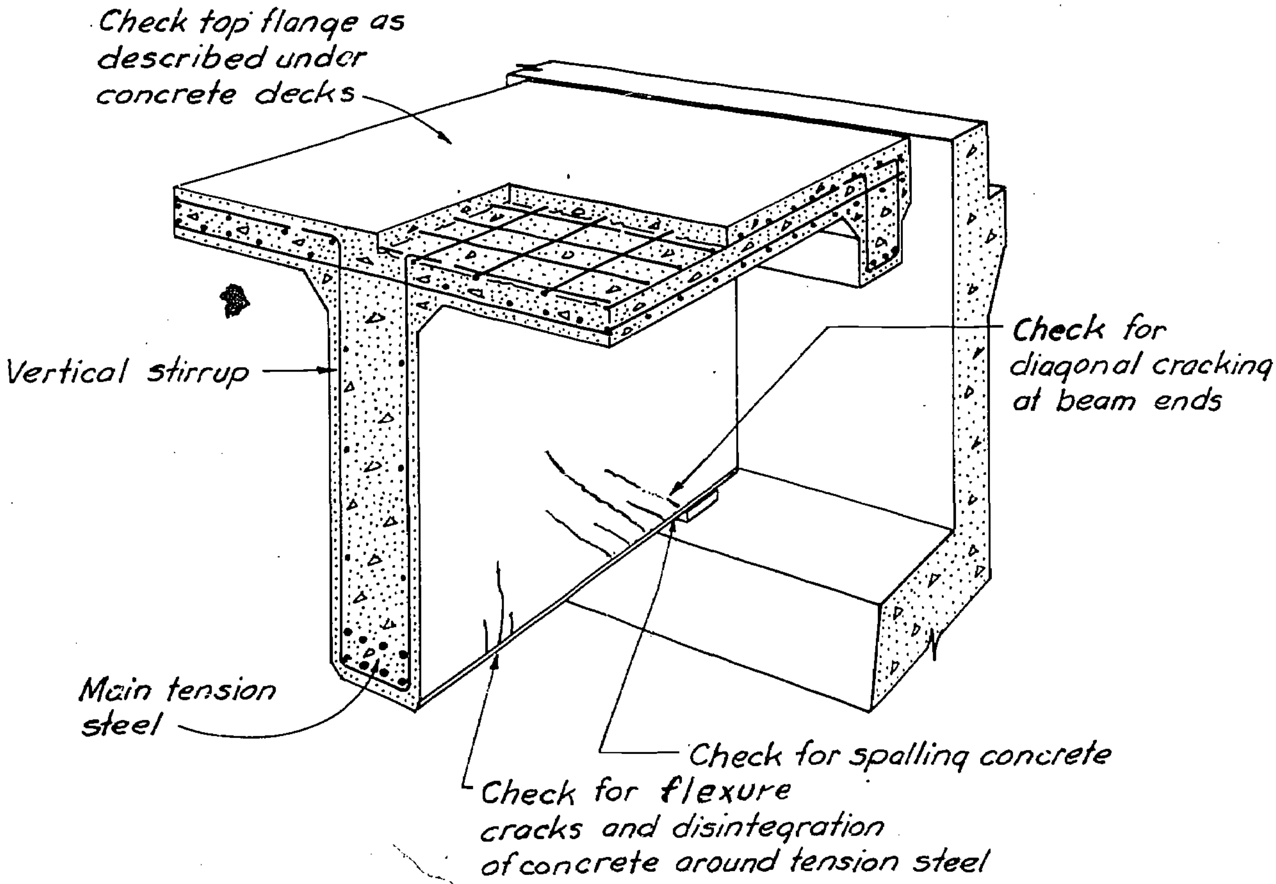



*Figure 5–50. Concrete beam checklist items.*

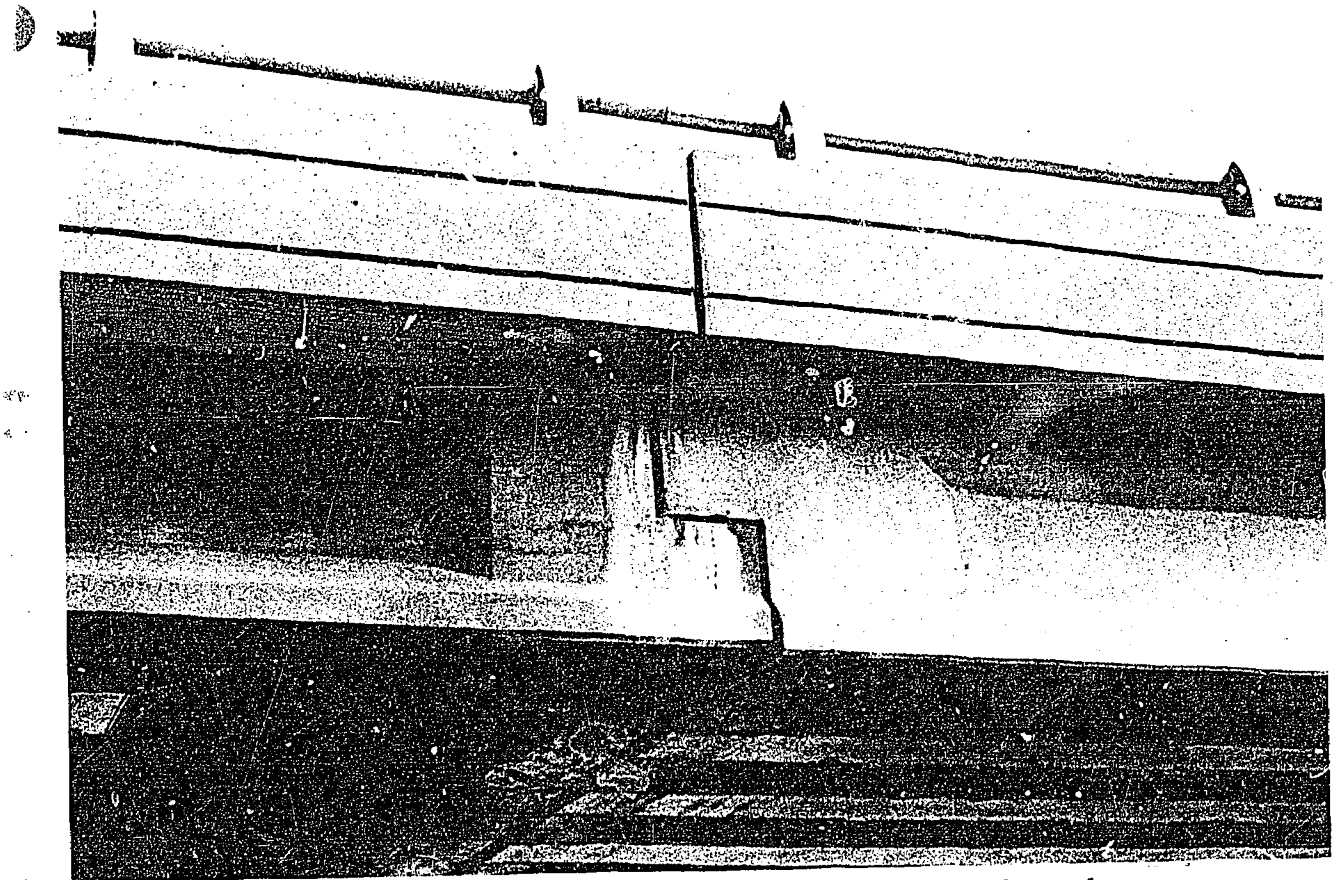


*Figure 5–51. Ship-lapped cantilever between a reinforced concrete box and a prestressed concrete suspended span. Note stains caused by roadway drainage. This may be a source of future deterioration.*

## Section 13. STEEL BEAMS AND GIRDERS

### 5–13.1 General.

a. Steel beams and girders which are classed as main members, transmit all deck loads to the substructure of the bridge. There are three general types of steel beams and girders:

(1) *Rolled (Wide Flange) Sections.* These may be either cover plated or plain, and are usually used in the construction of bridge spans of 100 feet or less (fig. 5–52).

(2) *Built-up Sections (Plate Girders).* This type of beam is normally used in the construction of bridge spans of 70 feet or longer in length.

(3) *Steel Box Girders.* These are used for certain special applications, e.g., where additional torsional resistance is required.

b. Steel beams and girders may be used in the construction of simple, continuous, or cantilevered bridge spans. Joints and connections may be either welded, riveted, bolted, or pinned (fig. 5–53).

c. The function of the intermediate vertical and longitudinal stiffeners on the thin webs of large built-up members is to prevent web buckling. Bearing stiffeners transmit shear to the web and prevent web crippling.

### 5–13.2 What to Look for During Inspection.

a. Inspect steel for corrosion and deterioration (fig. 5–54) especially at the following places:

(1) Along the upper flange

(2) Around bolts and rivet heads

(3) At gusset, diaphragm, and bracing connections

(4) At cantilever hanger and pin connections

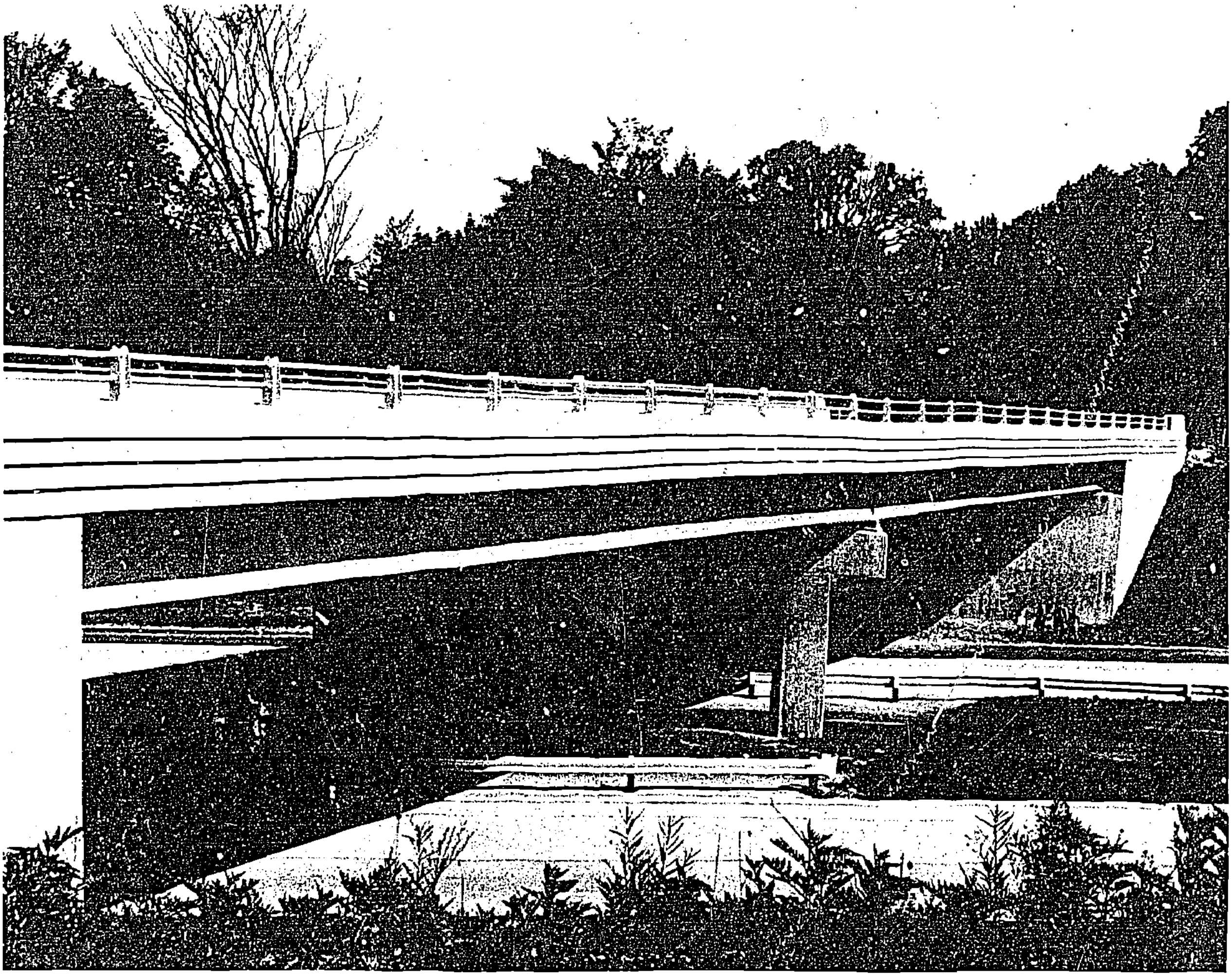


*Figure 5–52. Continuous steel wide-flange bridge.*

(5) Under the deck joints and at any other points that may be exposed to roadway drainage.

(6) At any point where two plates are in face to face contact and water can enter (such as between a cover plate and a flange). If rusting occurs at this interface, the expansive force created will be great enough to spread the plates.

(7) At the fitted end of stiffeners.

(8) At the ends of beams where debris may have collected.

b. If rusting and deterioration is evident, check the members for possible reduced cross sectional area, using calipers, rulers, corrosion meters, or section templates.

c. Examine areas around rivets or bolts and along the seams of built-up members and splices for deterioration and signs of slippage.

d. Check members for cleanliness and freedom from debris, especially on the top side of the bottom flange.

e. Examine welds, weld terminations, and adjacent metal for cracks, particularly at:

(1) Unusual types of weld connections or connections to which access would have been difficult for the welder.

(2) Connections transmitting heavy torsional or in-plane moments to the members. Typical connections of this type are:

(a) Floor beam to girder connection, where either the floor beam or girder is contin-

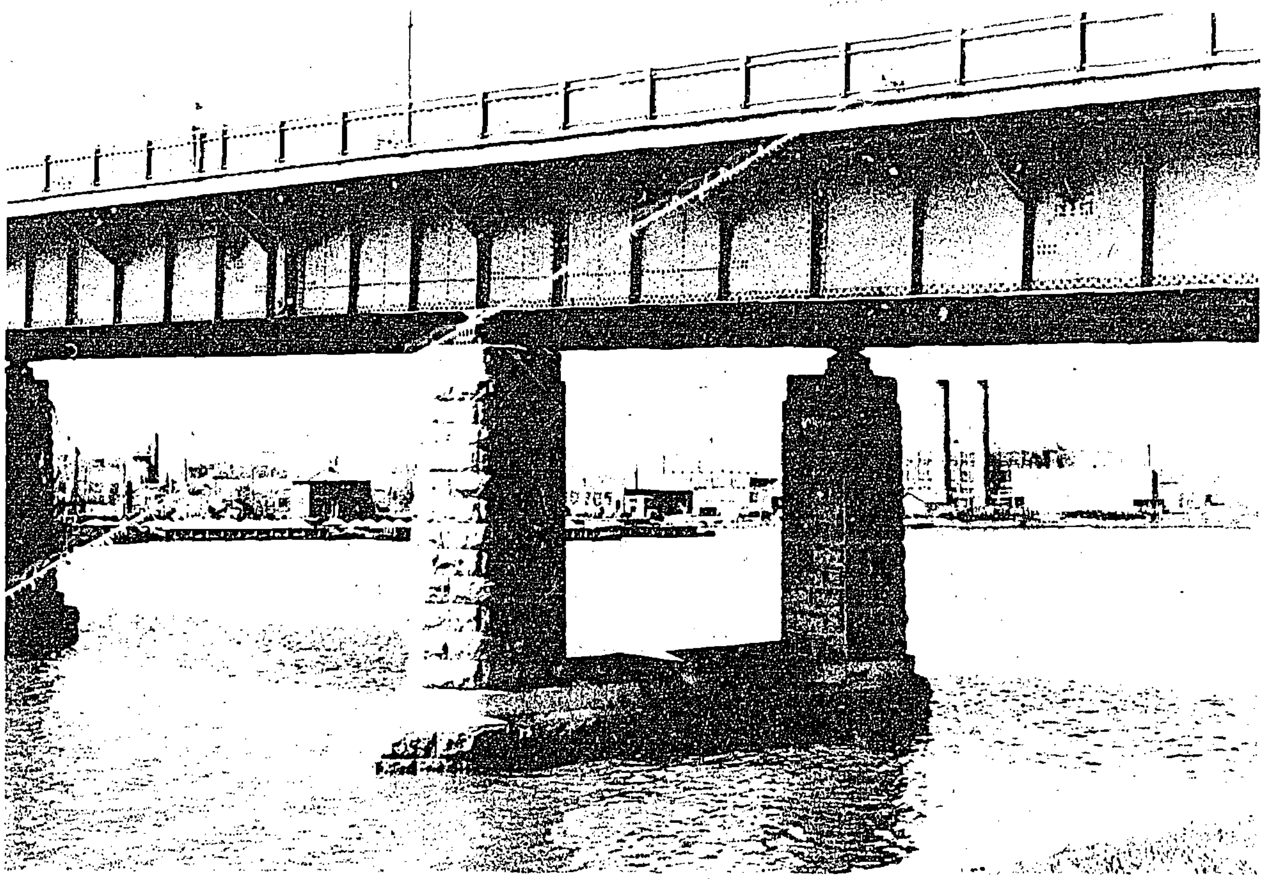


*Figure 5–53. Riveted steel girder bridge.*

uous through the other. (Steel pier caps are a special type of floor beam.)

(b) Brackets cantilevered from the fascia beams (or any cantilever connection from a beam).

(c) Moment splices.

(d) Joints in rigid frame structures or in vierendeel-type bracing.

(3) Sudden changes in cross-section or configuration or other locations subject to stress concentrations or fatigue loadings.

(4) Areas where vibration and movement could produce fatigue stress.

(5) Longitudinal stiffener connections. Whether these longitudinal stiffeners are also welded to the transverse stiffeners or are purely ornamental, the possibility of web and weld cracking is high.

(6) At unusual type connections, on curved sections, re-entrant corners, and copes.

f. Check the general alignment by sighting along the members. Misalignment or distortion may result from overstress, collision, or fire damage. If such a condition is present, its effect on structural safety of the bridge should be fully investigated.

g. Check for wrinkles, waves, cracks, or damage in the web and flanges of steel beams, particularly near points of bearing. This condition may indicate overstressing. Check the stiffeners for straightness and determine whether their connections are broken, buckled, or pulled from the web.

h. Determine whether any unusual vibration or excessive deflections occur under the passage of heavy loads.

i. On cantilevered bridges, check hinges and hangers to see that they are functioning freely and without restraint due to scoring, jamming, dirt, or corrosion.

(1) If a hanger link is out-of-plumb beyond the limits expected for normal temperature variations, a further investigation should be made.

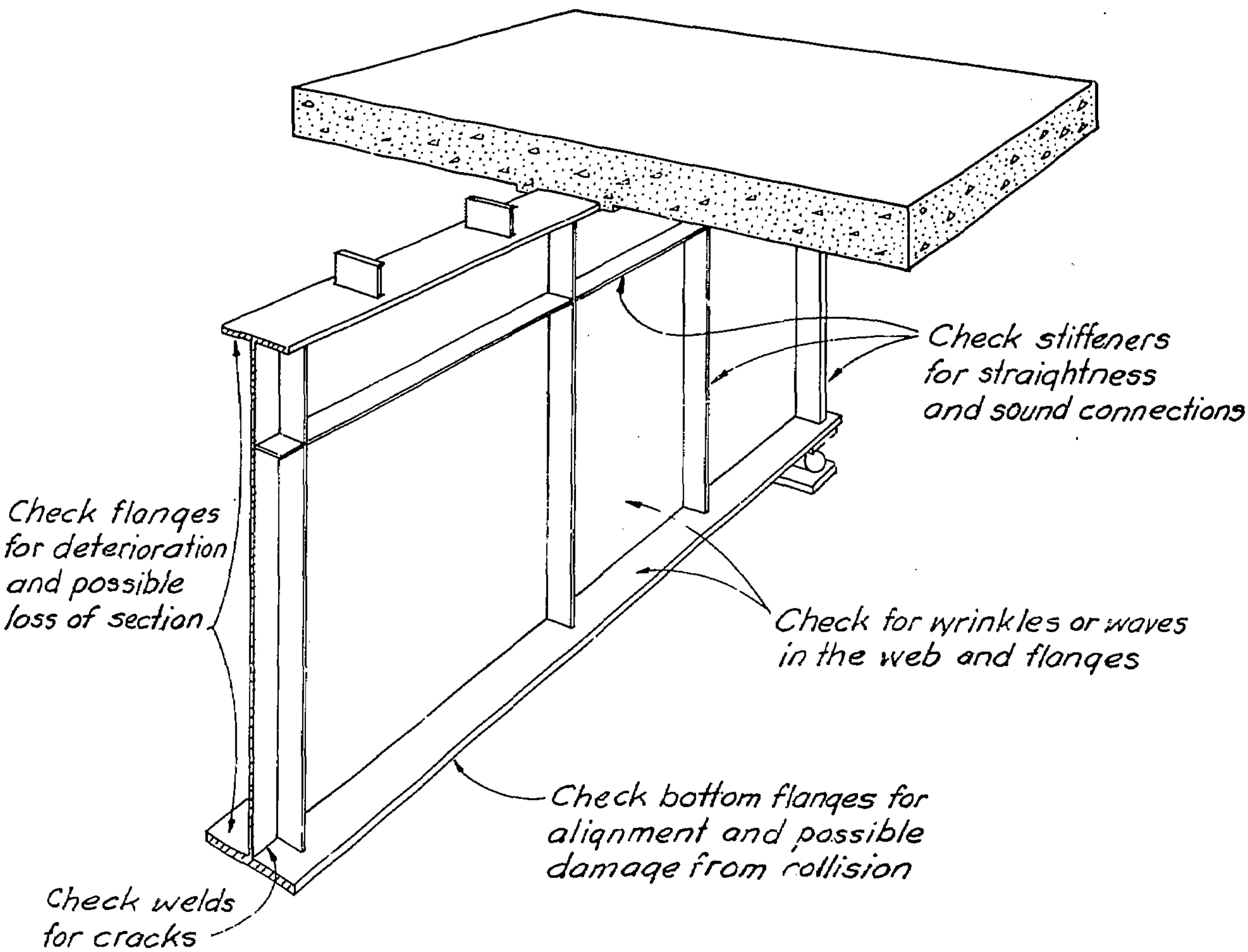



*Figure 5–54. Steel girder checklist items.*

(2) Where a hanger has one end fixed rigidly to web by welding or bolting, so as to develop an eccentric hinge, the hanger will develop both bending and axial stresses. Examine the web and the hanger adjacent to its fixed end for cracking.

j. Check the wind locks for:

(1) Excessive movement before engaging.

(2) Binding, jamming, or improper fit.

k. Do not overlook the inside of box girders.

## Section 14. FLOOR SYSTEMS

### 5–14.1 General.

Bridge decks are supported on three different types of floor systems. The simplest floor system is that in which the decking or slab is carried directly on the main girders or primary stringers. This type of floor system can be made from steel, timber, prestressed or reinforced concrete beams. Concrete and steel beams are discussed in Sections 5–12 and 5–13. Bridge decks are discussed in Section 5–20. For longer span bridges a stringer and floor beam network transfers the deck load to the main girders or trusses (figs. 5–55 and 5–56). Where the long span bridge is sufficiently narrow, the secondary stringers are often omitted and the deck slab is carried longitudinally between floor beams.

### 5–14.2 Functions and Composition.

a. Floor beams are transverse members which support the stringers and transmit the load to the main girders or load carrying members. Steel pier caps on reinforced concrete pier columns are a special type of floor beam. Floor beams are usually rolled beams, built-up sections, or trusses.

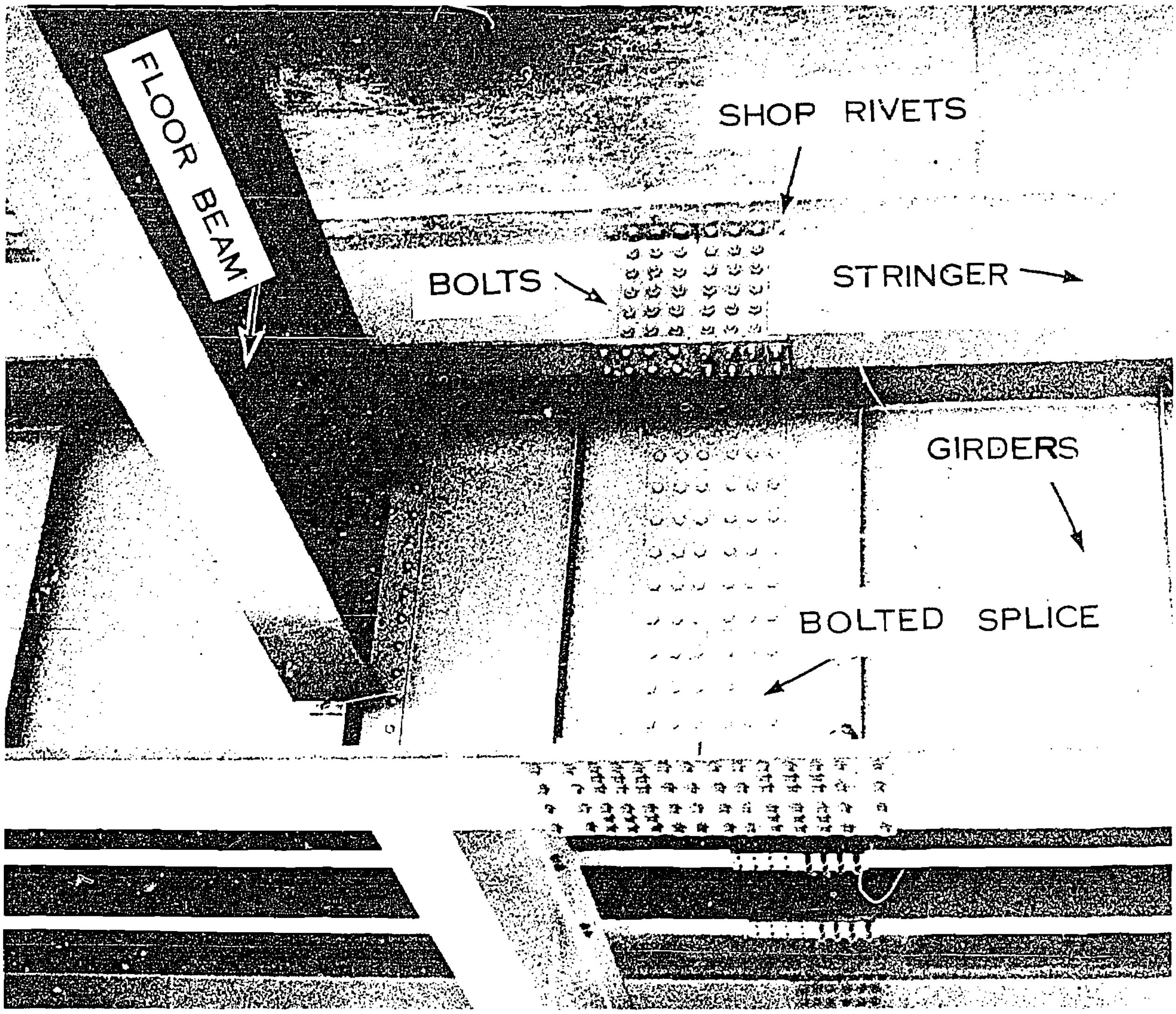



*Figure 5–55. Steel girder and stringer bolted splice details.*

b. Stringers are longitudinal members which span between floor beams or piers and abutments to provide deck support. Deck stringers are usually steel WF-beams, timber, concrete T-beams, or prestressed concrete members.

### 5–14.3 What to Look for During Inspection.

a. *Floor Beams* (fig. 5–57).

(1) The end connections of floor beams should be checked carefully for corrosion. This is particularly critical on truss bridges where the end connections are exposed to moisture and deicing chemicals from the roadway.

(2) The top flange of floor beams should be checked for corrosion, especially near the end connections and at points of bearing.

(3) Check the floor beams to determine if they are twisted or swayed. This situation occasionally develops as a result of the longitudinal forces that are exerted by moving vehicles on the floor beams. It occurs primarily on older structures where the floor beams are simply supported and where the stringers rest upon the floor beam.

(4) On end floor beams, examine the connections thoroughly for cracks in the welds and for slipped rivets or bolts.

b. *Stringers.*

(1) *Steel.*

(a) Check for rust or deterioration, especially around the top flange where moisture may accumulate from the floor above and at the

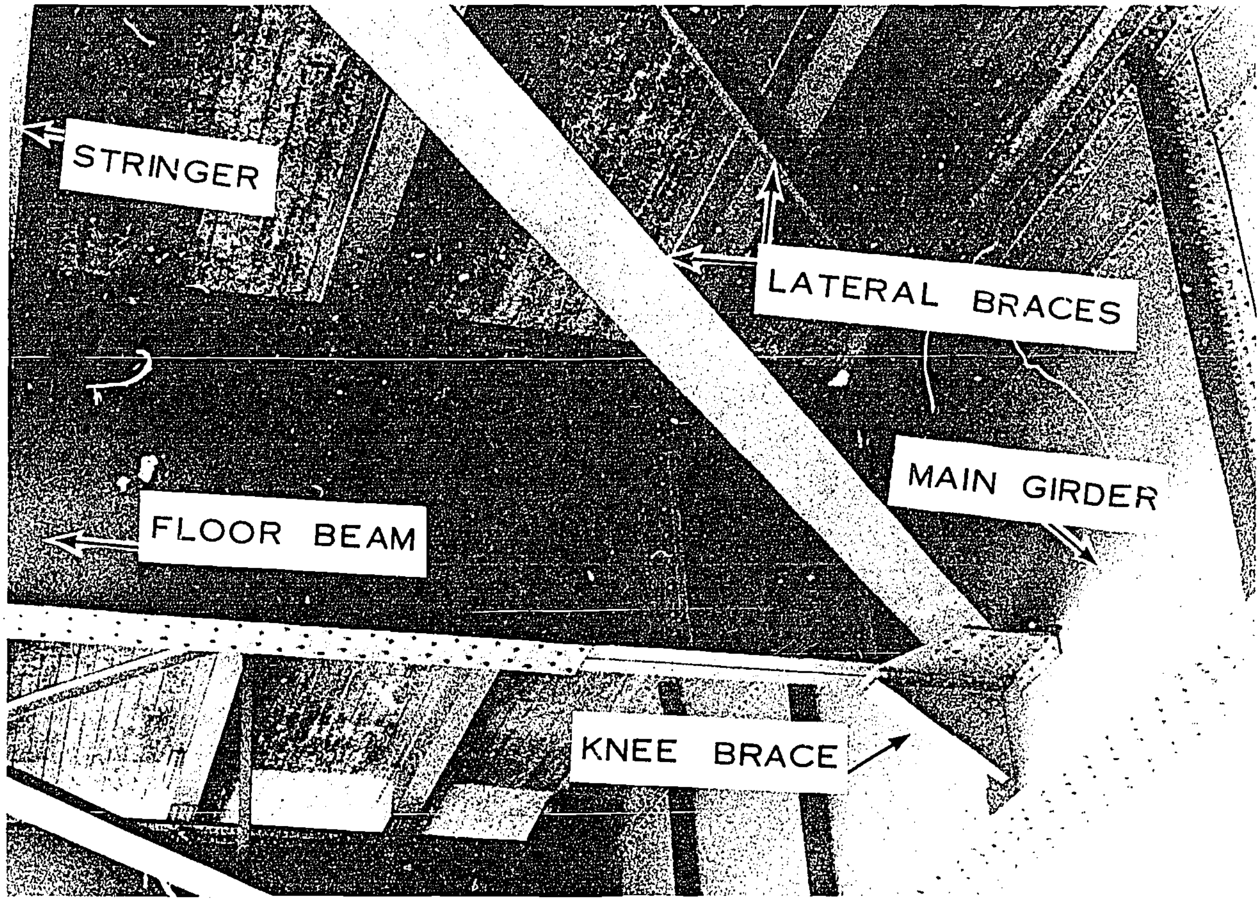



*Figure 5–56. Floor system of steel two-girder bridge.*

end connections around rivets, bolts, and bearings.

(b) Check for sagging or canted stringers.

(c) Inspect all stringer connections for loose fasteners and clip angles (fig. 5–58). Where stringers are seated on clip angles check for cracks in the floor beam web.

(2) *Timber.*

(a) Check for crushing and decay, especially along the top where the decking comes in contact with the stringer, and at points at which the stringer bears directly upon the abutment and bent caps.

(b) Check for horizontal cracks and splitting, especially at the ends of stringers, where they are often notched.

(c) Check for sagging or canted stringers.

(d). Check the bridging between the stringers to determine whether it is tight and functioning properly.

(e) Check for accumulations of dirt and debris.

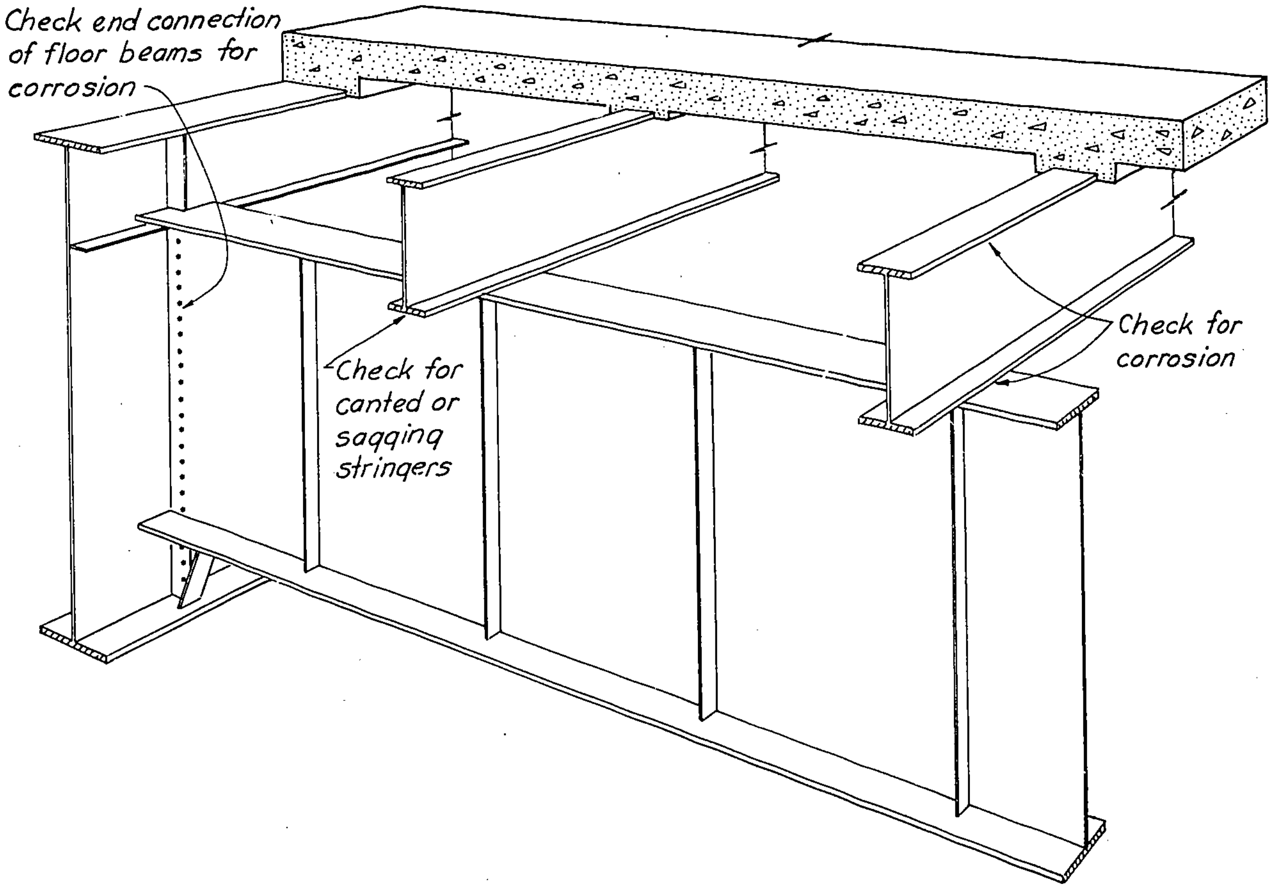
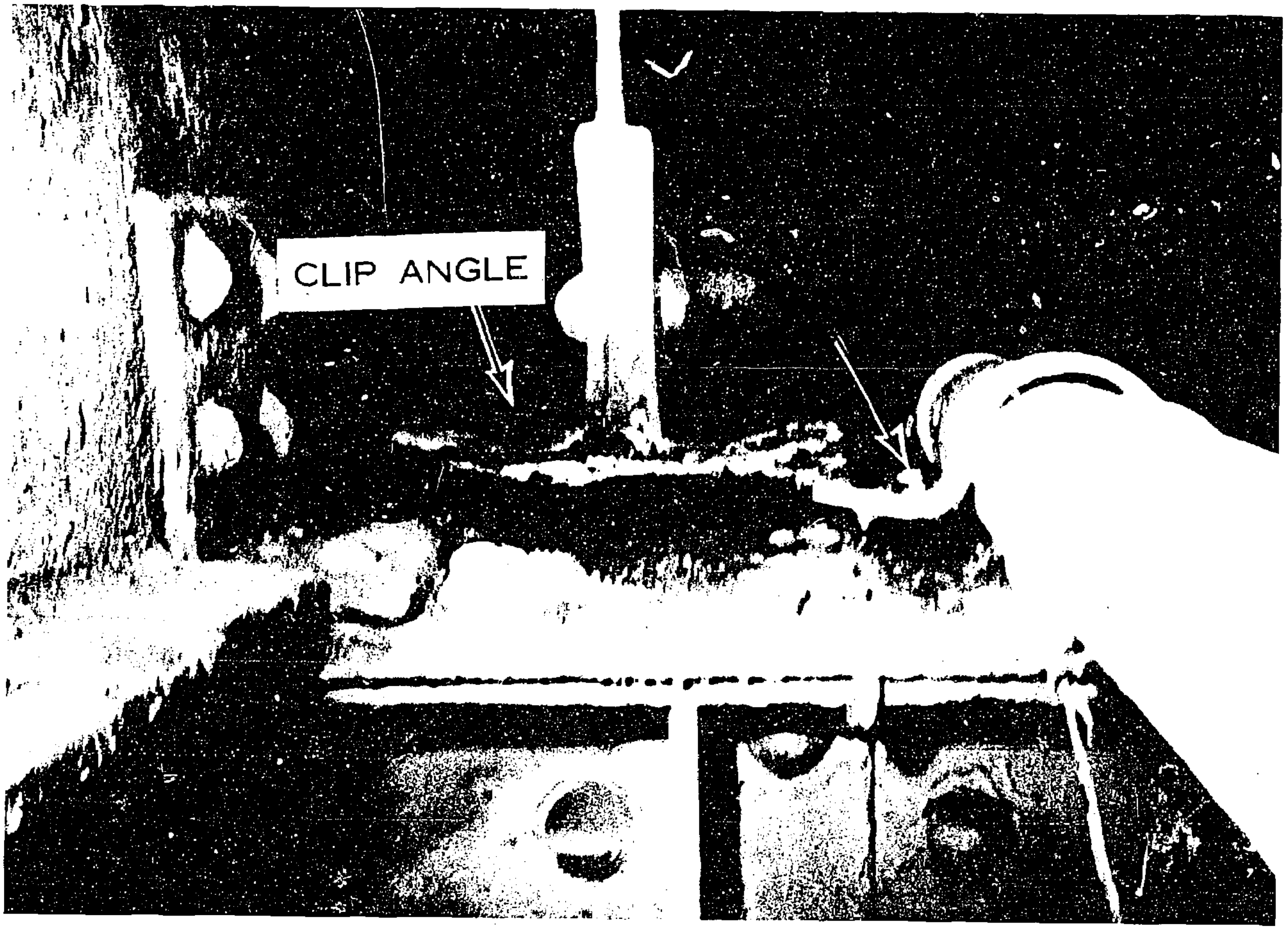



*Figure 5–57. Steel floor beam and stringer checklist items.*




Courtesy of District of Columbia Highway Dept.

*Figure 5–58. Stringer support connection. Note effect of corrosion on horizontal legs of clip angles. Note also loose connection on utility pipe.*

### *Section 15. TRUSSES*

#### 5–15.1 General.

a. *Function.* A truss consists of members which are generally under axial loading only, i.e., tension or compression. Its greatest usefulness is in bridges with relatively long spans where dead load is a problem. Trusses are generally considered to be main members, but are also used as floor beams or bracing (fig. 5–59).

b. *Composition.* While most trusses are of steel, timber trusses are still used (fig. 5–60). Truss members may be connected with rivets, bolts, or pins. Although the configuration of trusses varies widely, the essential components are common to all (fig. 2–10). 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 (fig. 5–61) and stay plates (fig. 5–61) at the ends. While new perforated cover plates have replaced lacing, and newer bridges sometimes use closed box sections, many other section types will be found. 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."

#### 5–15.2 What to Look for During Inspection.

a. *Steel trusses.*

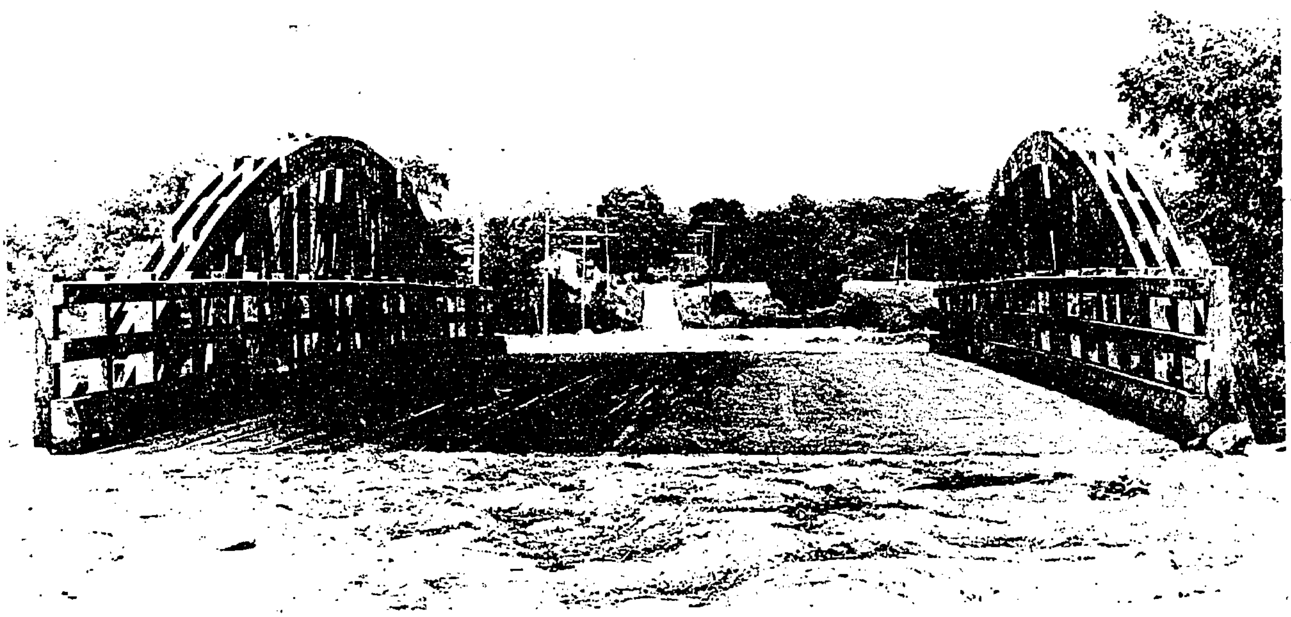
(1) *Rust and Deterioration.* On through trusses (fig. 5–62) moisture and deicing chemicals from the roadway are often splashed on the lower chord members and the members adjacent to the curb (fig. 5–63 and 5–64). The mois-

*Figure 5–59. Deck truss bridge.*

ture and chemicals are retained at the connection and between the adjacent faces of eye bar heads, pin plates, etc., leading to rapid deterioration of the member. On riveted trusses, the horizontal surfaces and connections of lower chord members (fig. 5–65) are especially susceptible to corrosion. Debris tends to accumulate causing moisture and salt to be retained. Note any deformation caused by expanding rust on the inside surfaces of laminated or overlapping plates.

(2) *Alignment of Truss Members.* End posts and interior members are vulnerable to collision damage from passing vehicles. Buckled, torn, or misaligned members may severely reduce the load-carrying capacity of the truss. Misalignment can be detected by sighting along the roadway rail or curb and along the truss chord members. Investigate and report any abnormal deviations.

(3) *Overstressed Members.* Local buckling indicates overstress of a compression member. Wrinkles or waves in the flanges, webs, or cover plates are common forms of buckling. Overstress of a ductile tension member could result in localized contraction in the cross section area



Courtesy of Timber Structures, Inc.

*Figure 5–60. Timber truss.*

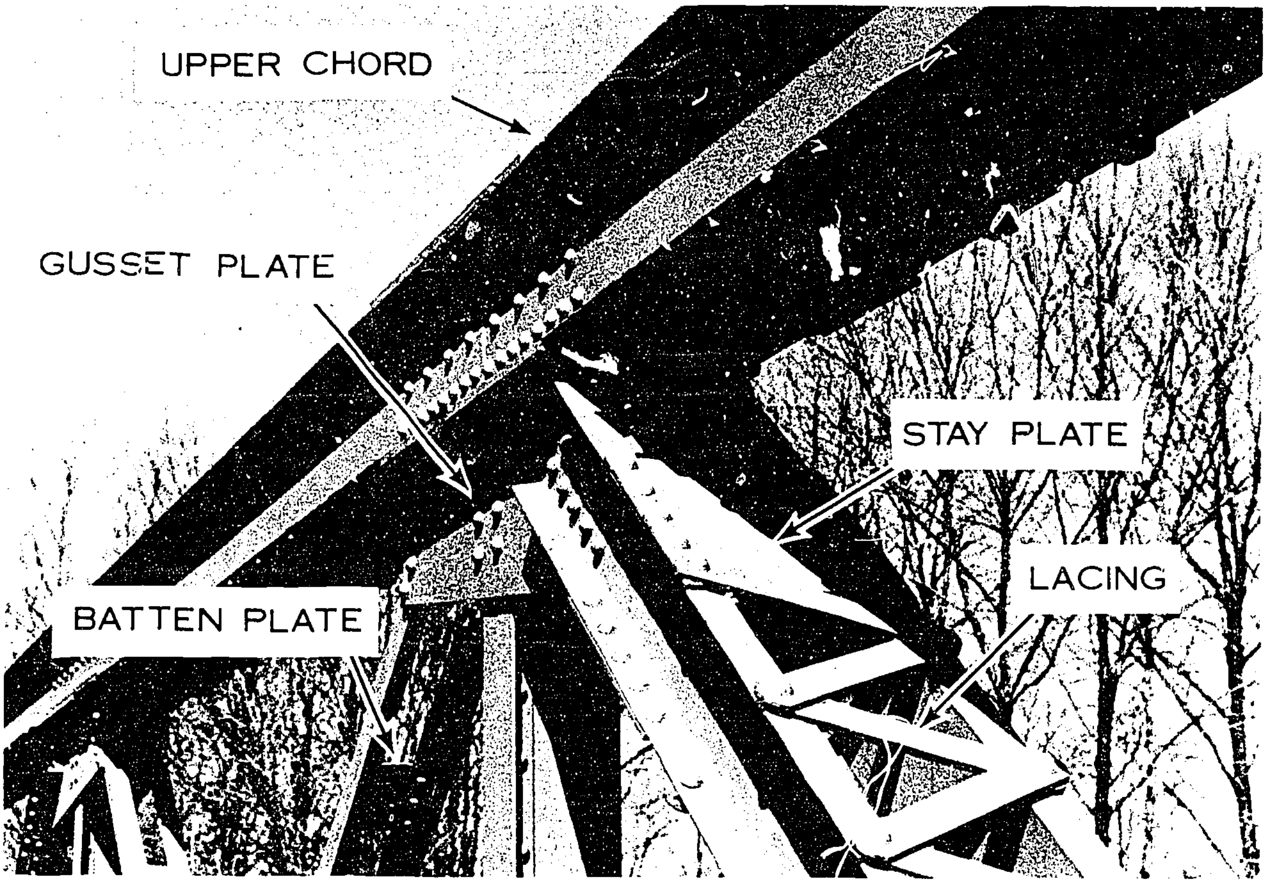



*Figure 5–61. Truss details.*

of the member. This is usually accompanied by flaking of the paint.

(4) *Loose Connections.* Cracks in the paint or displaced paint scabs around the joints and seams of gusset plates and other riveted or bolted connections may indicate looseness or slippage in the joints. Check rivets and bolts that appear defective.

(5) *Pins.* Inspect pins for scoring and other signs of wear. Be sure that spacers, nuts, retaining caps, and keys are in place.

(6) *Noise.* Note clashing of metal with the passage of live loads.

(7) *Tension Members.*

(a) Check each truss where there is more than one section in any tension member to see that stresses are evenly divided.

(b) Check counter members to see that they are in proper adjustment.

(c) Check looped rod tension members for abnormal cracking where the loop is formed.

(d) Examine eyebar members for cracks in the eyes.

(e) Determine whether the spacers on the pins are holding the eyebars and looped rods in their proper position.

(f) Check the physical condition of threaded members such as truss rods at turnbuckles.

b. *Timber Trusses.*

(1) Check for weathering, checking, splitting, and decay. Decay is often found at joints, caps, and around bolt holes. Decay is also common on the bridge seat.

(2) Check for crushing at the ends of compression chord and diagonal members.

(3) Examine splices carefully for decay. Note whether bolts and connections are tight.

(4) Check for decay at joints where there are contact surfaces, daps where moisture can enter, and around holes through which truss bolts are fitted.

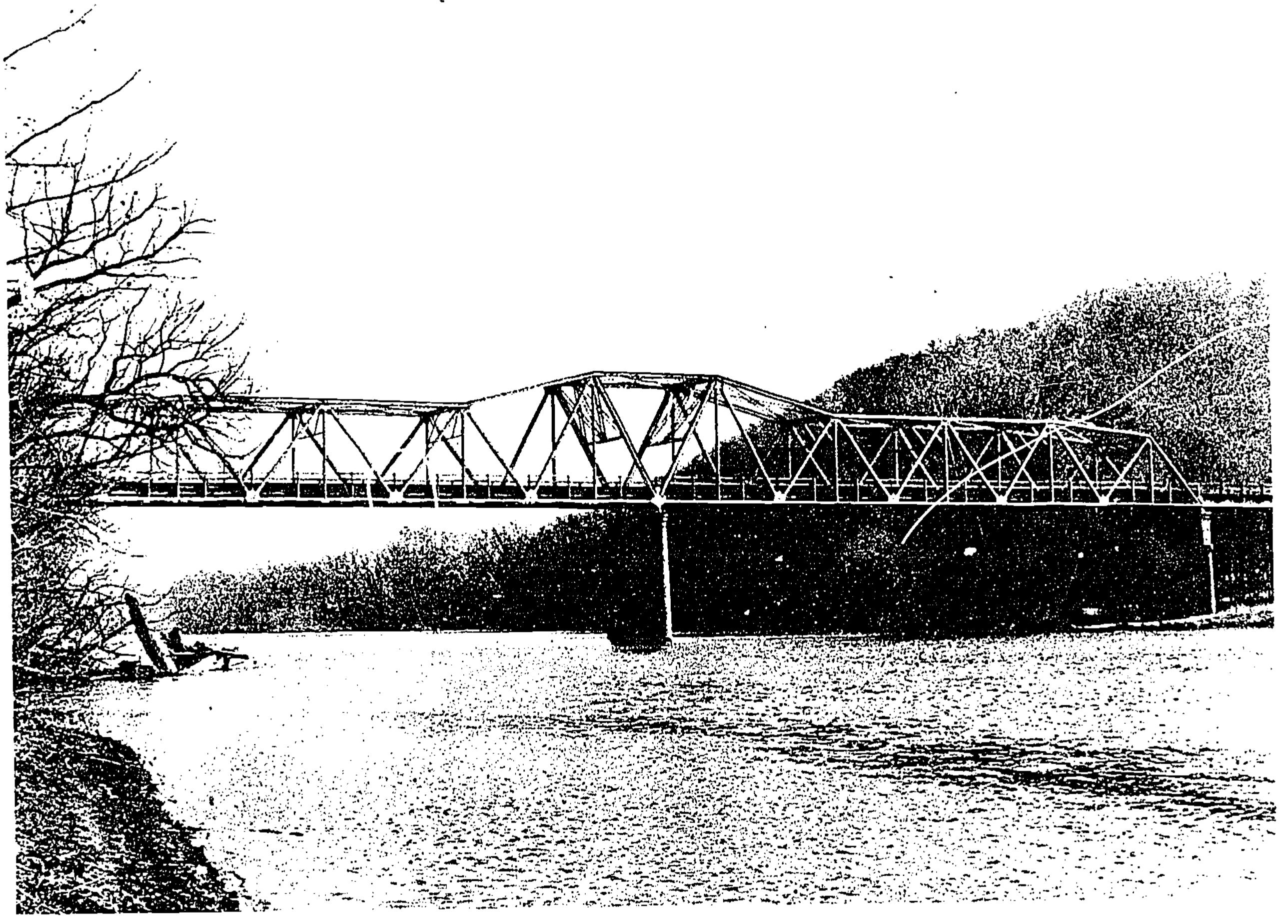


*Figure 5–62. Continuous through truss bridge.*

(5) Check end panel joints for decay.

(6) Check for dirt or debris accumulation on the bridge seat.

(7) Investigate the roof and sides of covered bridges for adequacy of protection afforded the structural members from the elements of weather.

(8) Check the alignment of the truss. Sagging of the truss may be due to the partial failure of joints or improper adjustment of steel vertical rods.

(9) Be particularly aware of fire hazards, such as:

(a) Brush or drift accumulating under the bridge.

(b) Storage of combustible material under the bridge.

(c) Parking of vehicles under the bridge.

(d) Signs of fires built by vagrants, children, or workmen under the bridge.

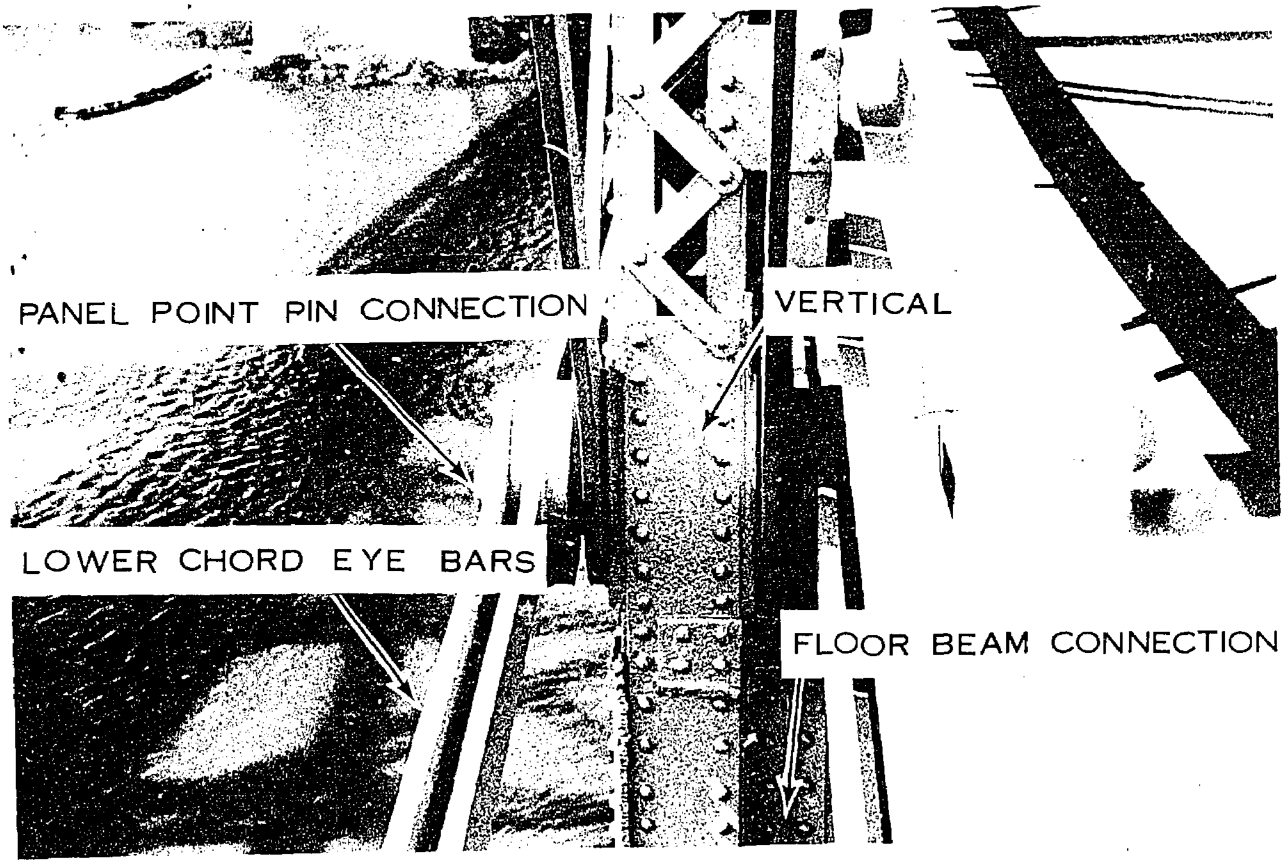



*Figure 5–63. Detail of lower chord panel point connection. Note that the pin connection and floor beam connection beneath are exposed to moisture and brine splashed from the roadway.*

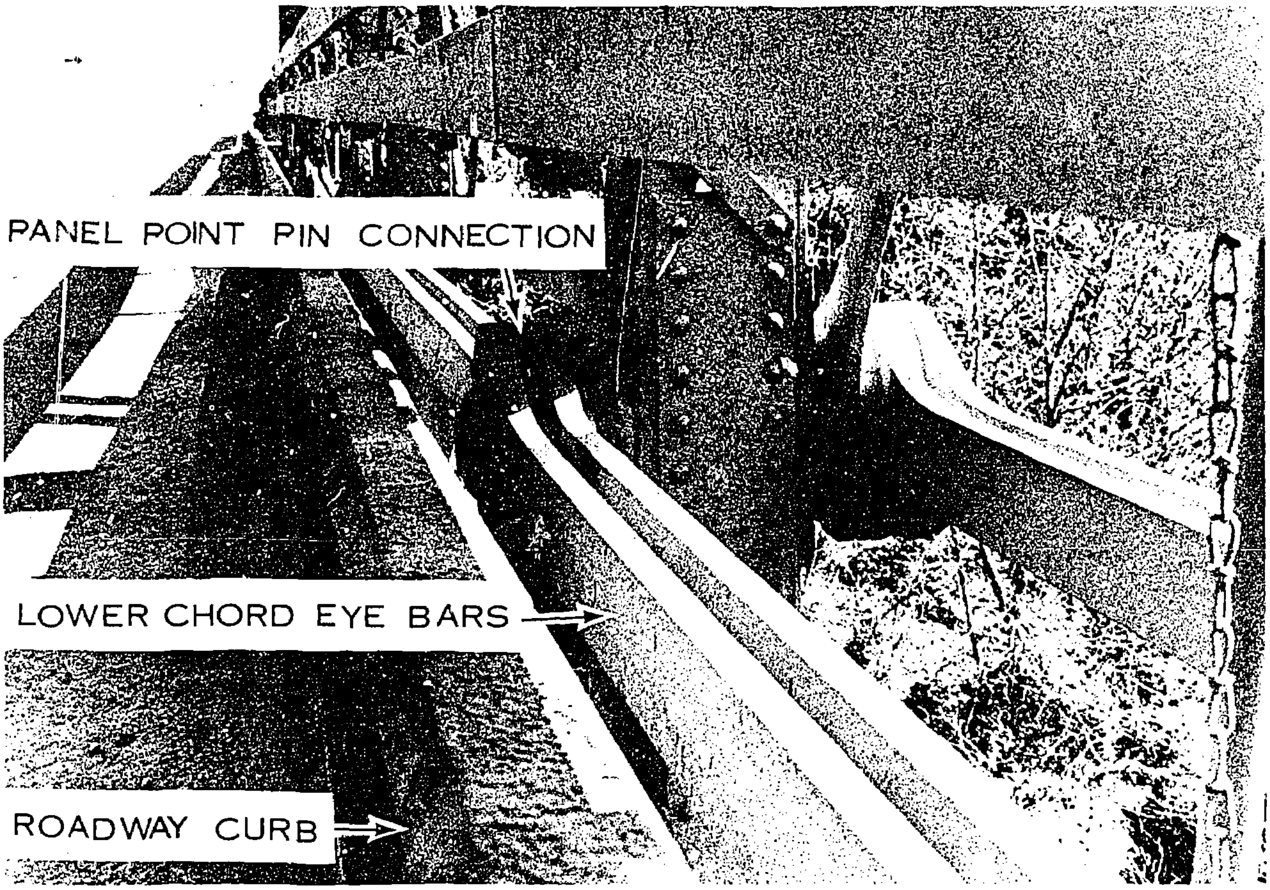



*Figure 5–64. Lower chord pin connection of eyebar truss. This type of connection is particularly susceptible to the effects of moisture and brine splashed from the roadway.*

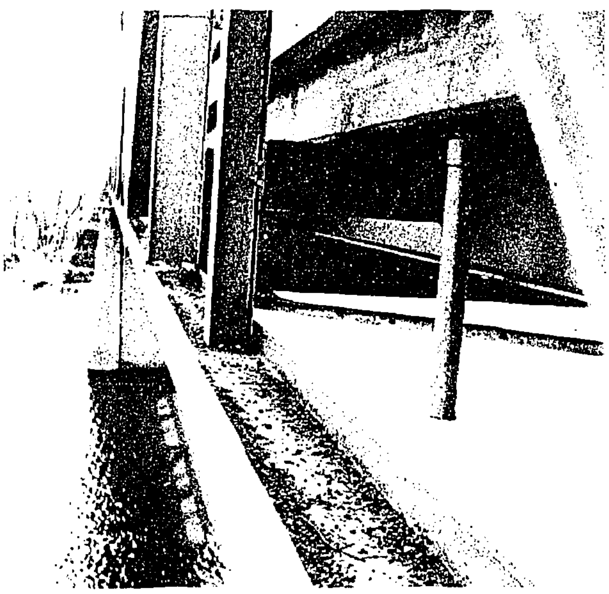


*Figure 5–65. Panel point connections along lower chord. Note the collection of debris along the horizontal surface of the bottom chord.*

## Section 16. DIAPHRAGMS AND CROSS FRAMES

### 5–16.1 General.

a. *Function.* Diaphragms are transverse members between the main beams, or stringers, which brace and stiffen the beams. They distribute loads laterally and resist torsion. The lower chord of a cross frame also serves as the strut in the bottom lateral bracing. End diaphragms support the end of the bridge deck slab and transmit lateral forces to the bearings. Where a heavy concrete deck is used, the main function of a diaphragm is to brace the beams prior to the casting of the deck.

b. *Construction.* Diaphragms on shallow steel stringer bridges are usually channel or wide flange beam sections connected to the stringer webs with plates or angles. Cross frames of structural tees or angles connected to stiffeners are commonly used on the deeper built-up beams. Concrete diaphragms cast monolithi-

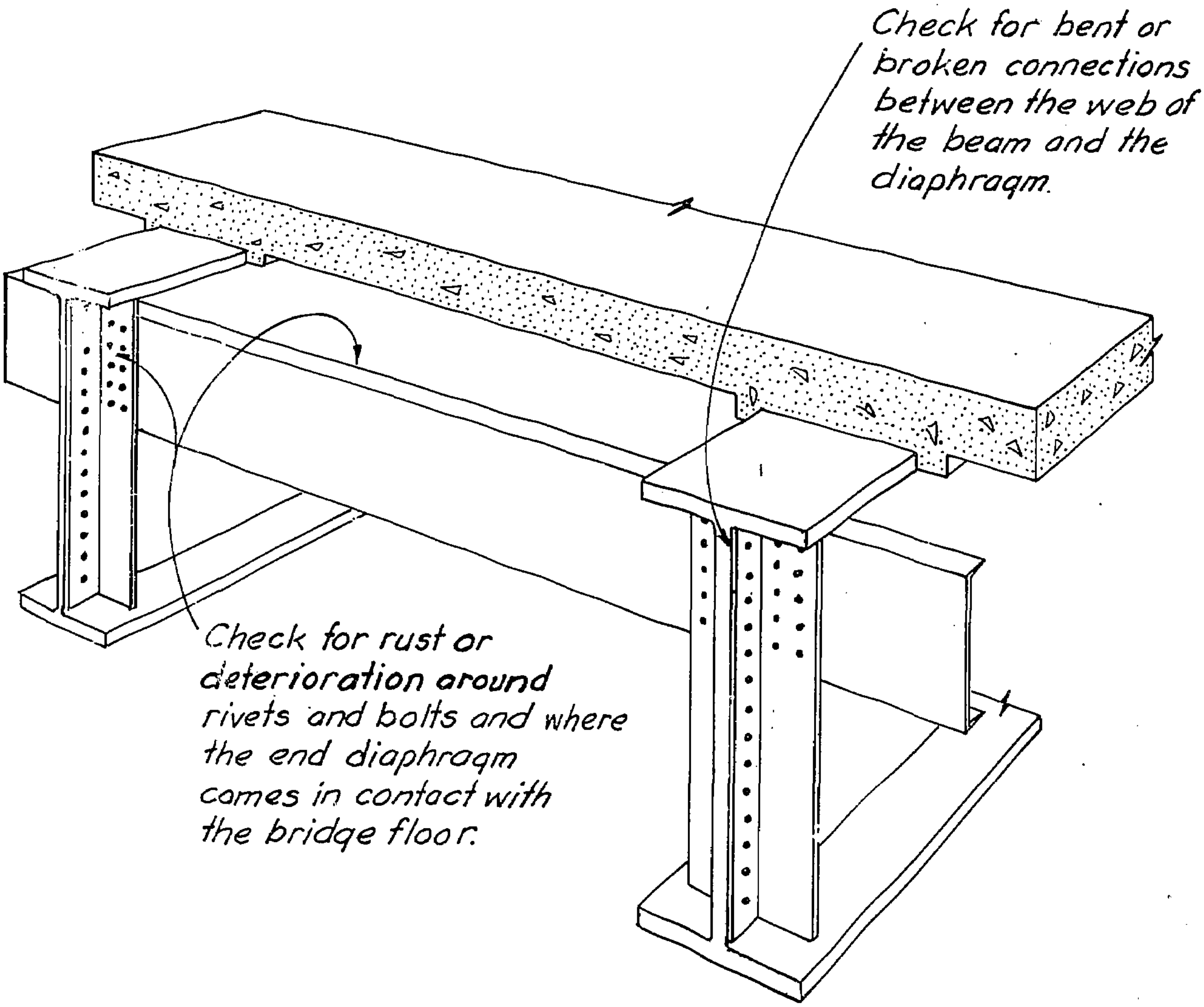



*Figure 5–66. Diaphragm checklist items.*

cally with the beams are ordinarily used on concrete bridges. On prestressed bridges, a rod or cable is sometimes threaded through the diaphragms to tie the beams together.

### 5–16.2 What to Look for During Inspection.

a. *Steel.*

(1) Check for loose or broken connections between the web of the beam or girder and the diaphragm (fig. 5–66).

(2) Check for rust or other deterioration, especially around rivets and bolts, and those portions of the end diaphragms which come in contact with the bridge floor. These may be particularly susceptible to corrosion from roadway moisture and from deicing agents.

(3) Look for buckled or twisted cross frames. This situation may be an indication of overstress of the bracing.

b. *Timber.*

(1) Check for cracking or splitting, especially in end diaphragms that are supporting the floor.

(2) Check for decay along the top of the diaphragms where they come in contact with the floor.

c. *Concrete.* Check for cracks, spalls, and for other forms of deterioration.

## Section 17. LATERAL BRACING PORTALS AND SWAY FRAMES

### 5–17.1 General.

a. *Function.* Bracing, the secondary system of members, distributes loads, stabilizes the bridge against torsional and wind loadings, prevents buckling of compression chords, and integrates the separate main member systems.

b. *Types.*

(1) *Diaphragms.* Diaphragms are discussed in Section 5–16.

(2) *Lateral Bracing.* On spans longer than 125 feet, a horizontal or lateral truss system (figs. 5–67 and 5–68) is provided to resist wind loads and to ensure a stable and rigid structure. A truss bridge usually has a lateral truss at both the upper and lower chord levels. On large girder bridges the concrete deck, together with the stringers and floor beams, generally serves the function of the upper lateral truss system. Therefore, unless the girders are very deep, only a lower lateral system is provided. The upper bracing, if present, is normally for construction purposes only. In the lower lateral bracing system, the floor beams or the cross frames serve as transverse struts; the lateral truss is formed by merely adding the diagonal members. On through trusses, the upper lateral truss is formed by the sway frame and portals in conjunction with the lateral bracing diagonals. Figures 5–69, 5–70, and 5–71 illustrate the details of a lateral bracing system.

(3) *Portals and Sway Frames.* Portals and sway frames are used to resist the sway and torsional effects of wind loads and other lateral forces. The portal is the heavy sway frame or girder across the top of the end posts of through trusses (figs. 2–10 and 5–72). The portal maintains the shape of the end cross section of the bridge and helps transfer the upper lateral forces to the bearings. Through girder bridges

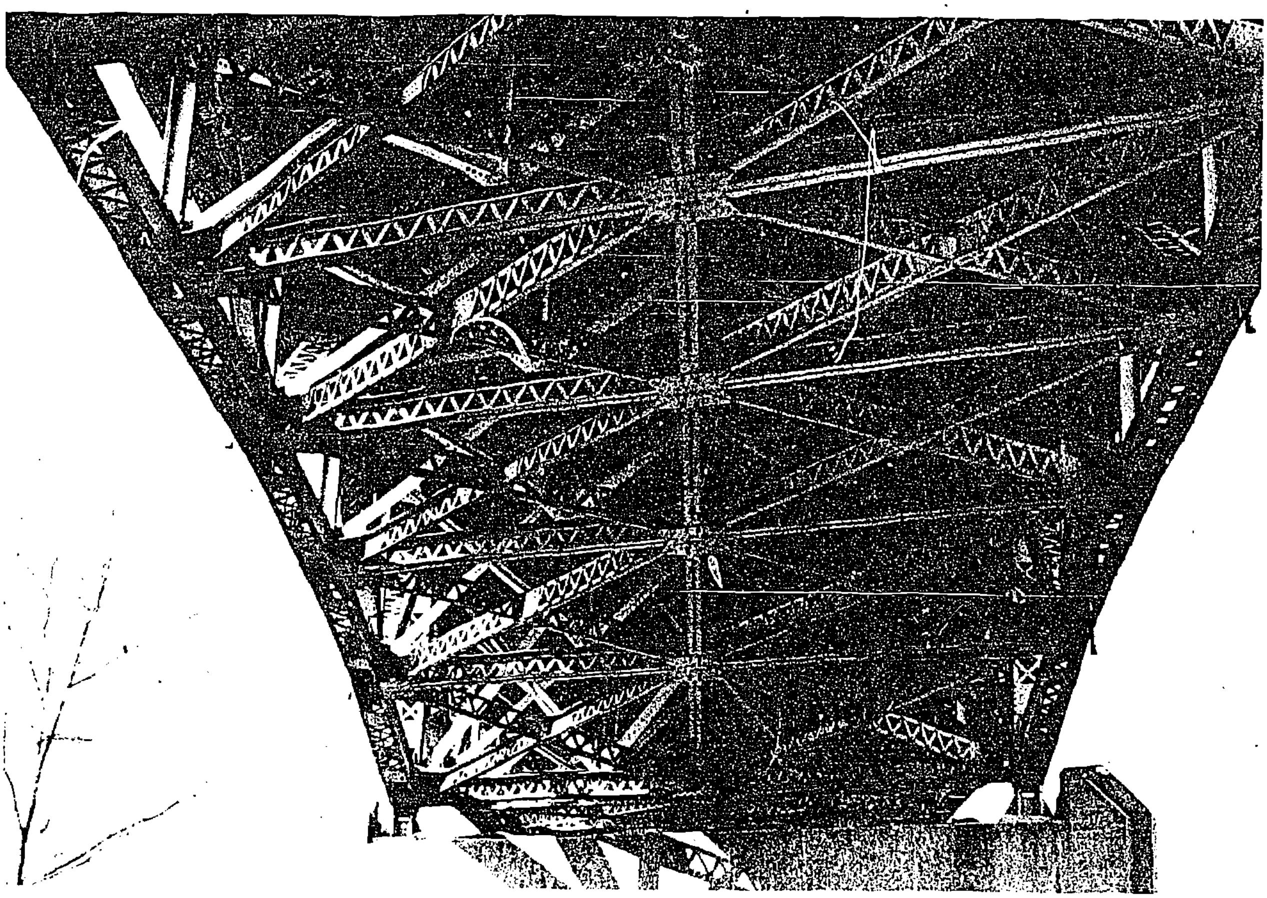


*Figure 5–67. Deck truss lateral bracing system.*

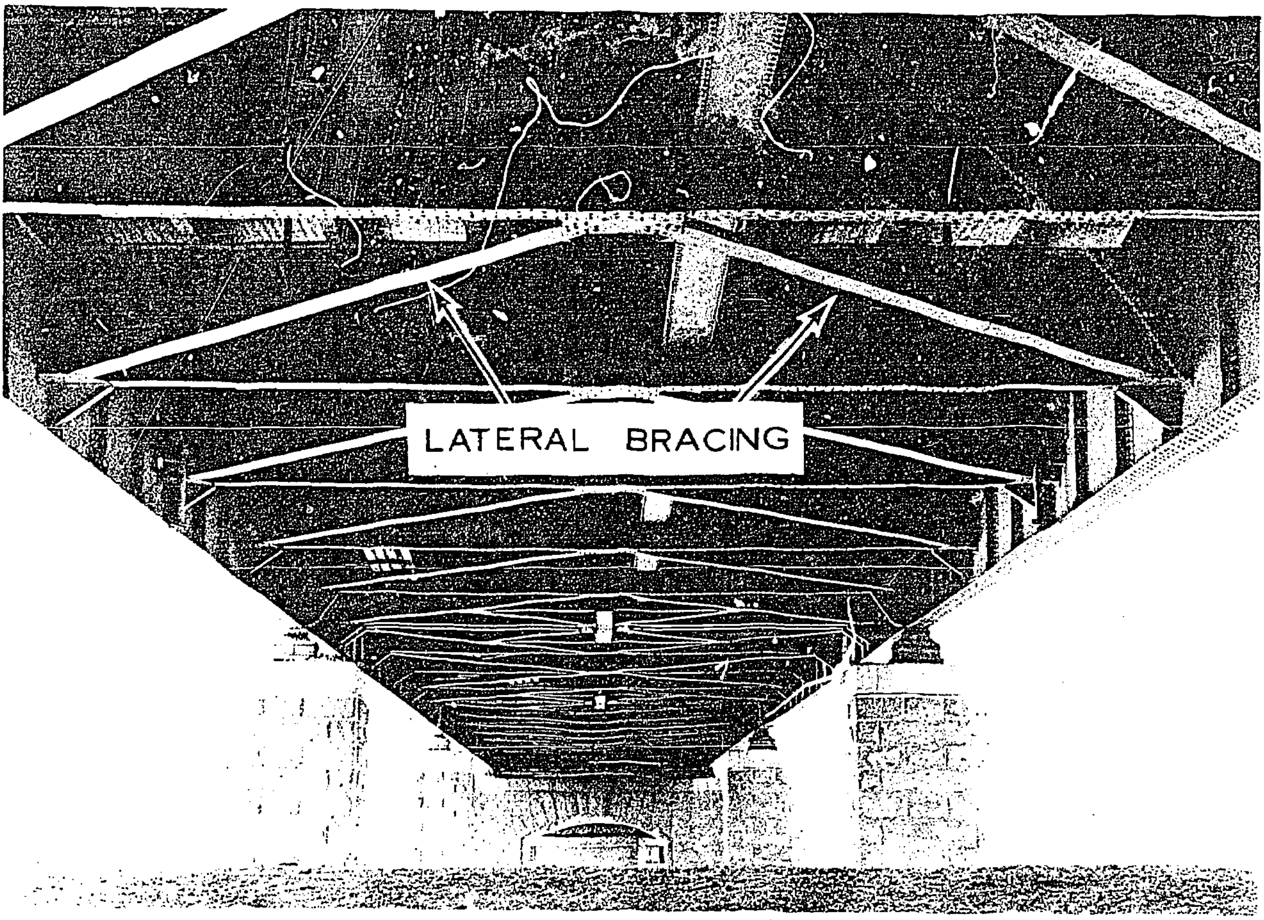



*Figure 5–68. Lateral bracing system on steel two-girder bridge.*

often use knee braces which laterally support the top flange of the girder.

c. *Composition.* Lateral bracing consists of angles, structural tees, pipes, tubes, wide-flange sections, or built up sections composed of channels, angles, and plates. The sway frames and portals are usually K-frames, or X-frames made of angles, tees, rolled beams, or a combination of members and are as deep as clearances permit.

### 5–17.2 What to Look for During Inspection.

a. Check all bracing members for rust, especially on horizontal surfaces such as those of lateral gusset plates and pockets without drains or with clogged drains.

b. Check for rust around bolts and rivet heads.

c. Look for loose or broken connections.

d. Check all upper and lower bracing members to observe whether they are properly adjusted and functioning satisfactorily.

e. Check for bent or twisted members. Since most of these bracing members work in compression, bends or kinks could significantly reduce their effectiveness. Since portals and sway braces necessarily restrict clearances, they are particularly vulnerable to damage from high loads.

f. Where lateral bracing is welded to girder flanges, inspect the welds and flanges for cracking.

g. Observe transverse vibration or movement of the structure under traffic to determine adequacy of lateral and sway bracing.

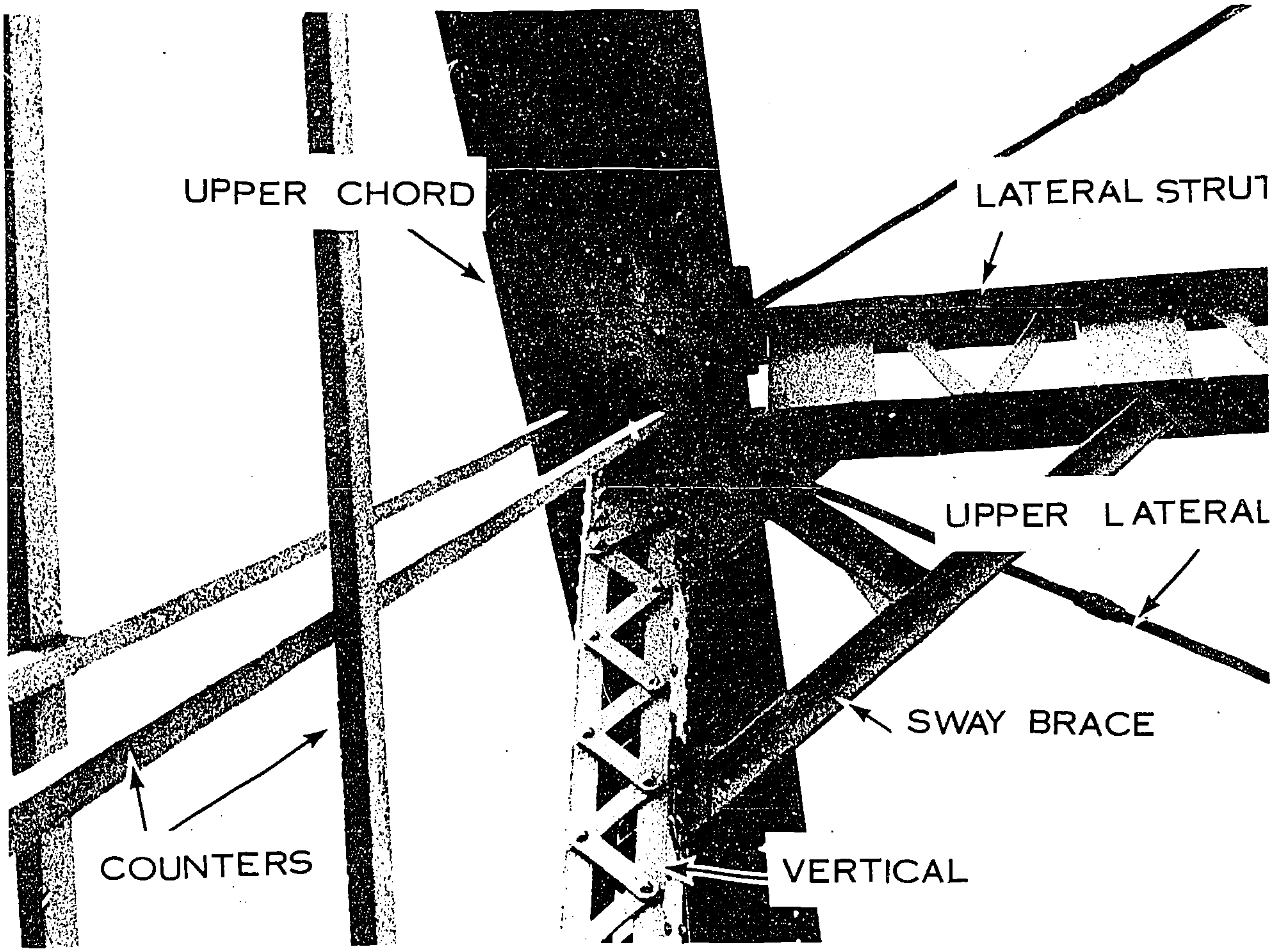



*Figure 5–69. Detail of sway brace and lateral strut connection.*

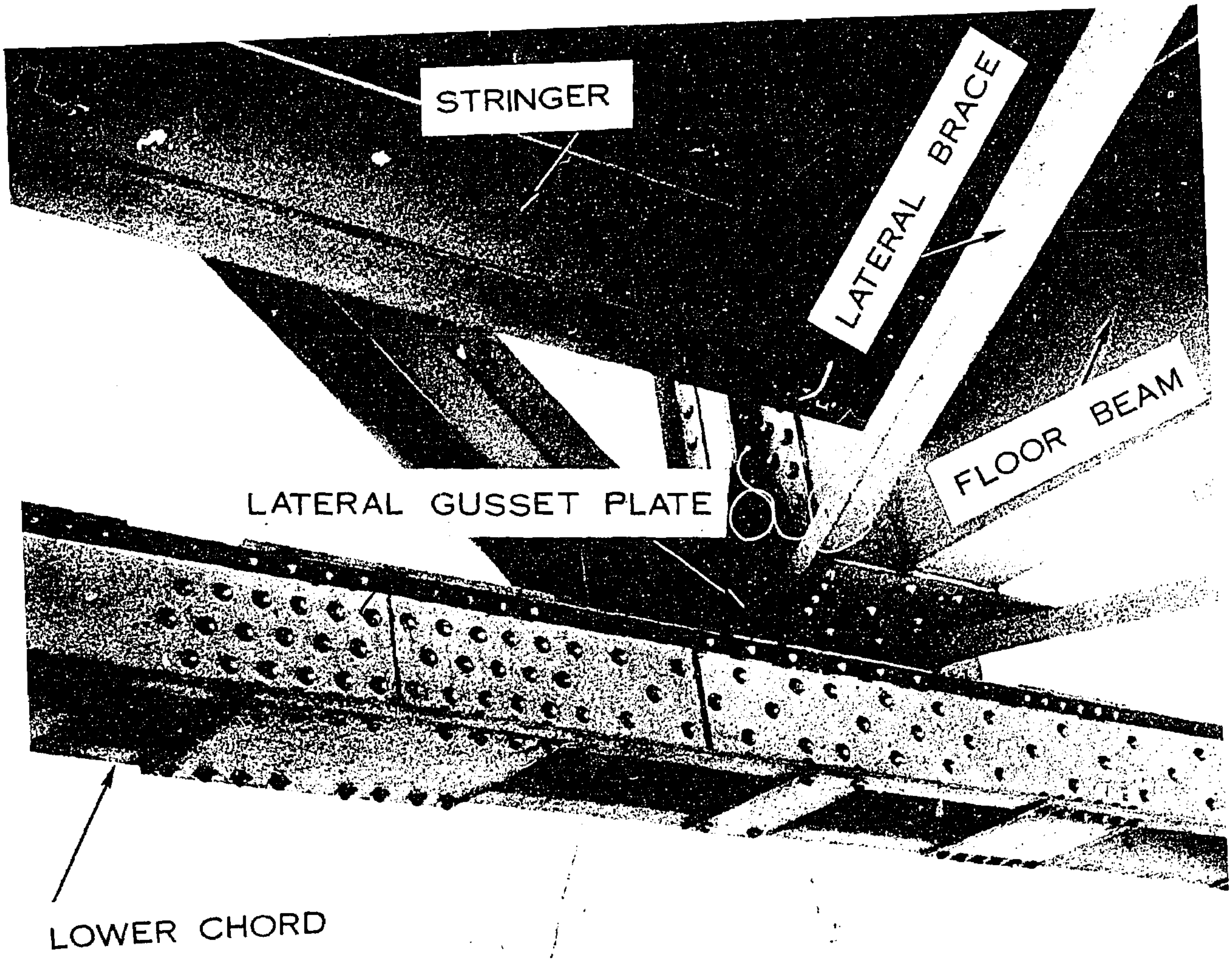



*Figure 5–70. Lower chord panel point showing lateral bracing connections.*

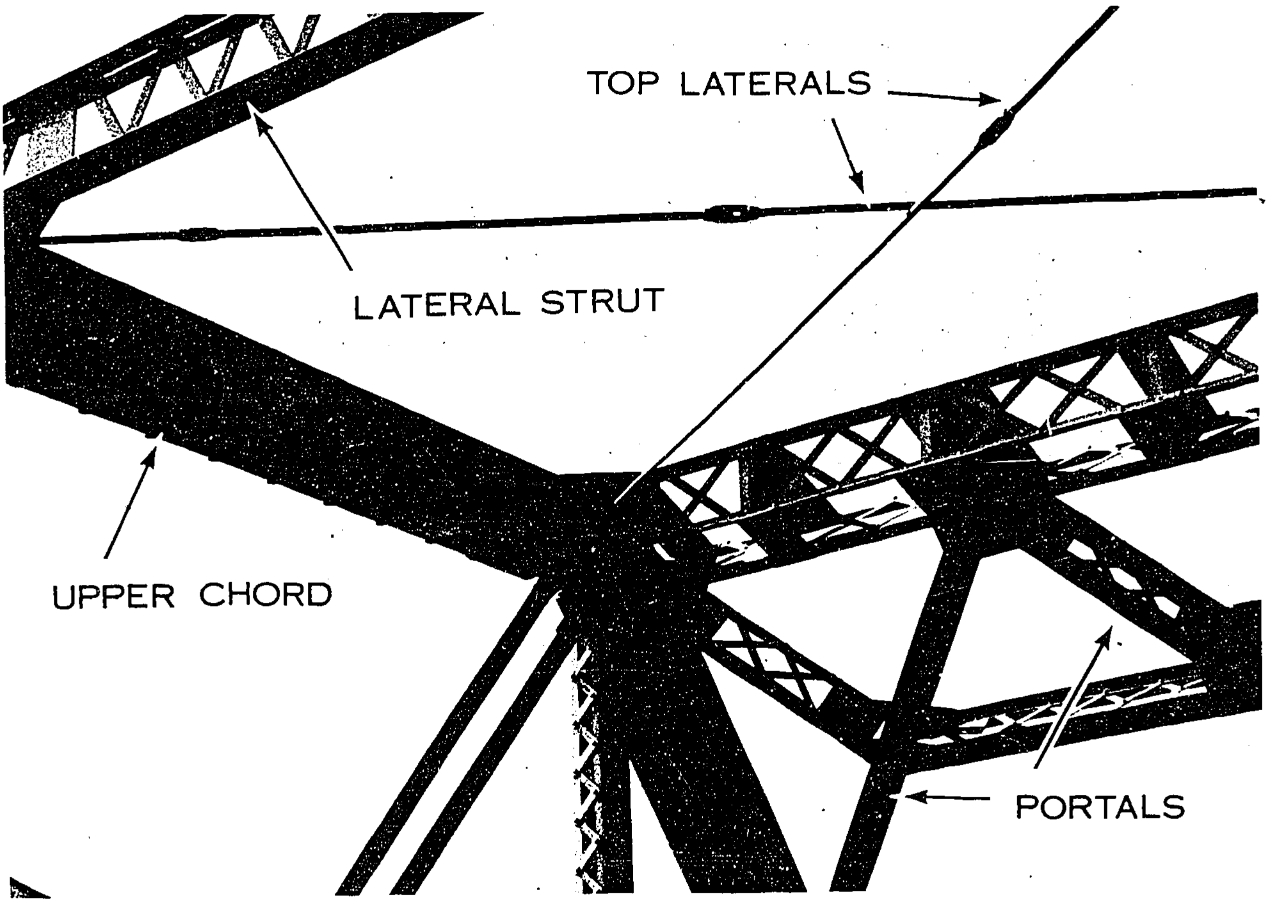



*Figure 5–71. Upper lateral system of through truss.*

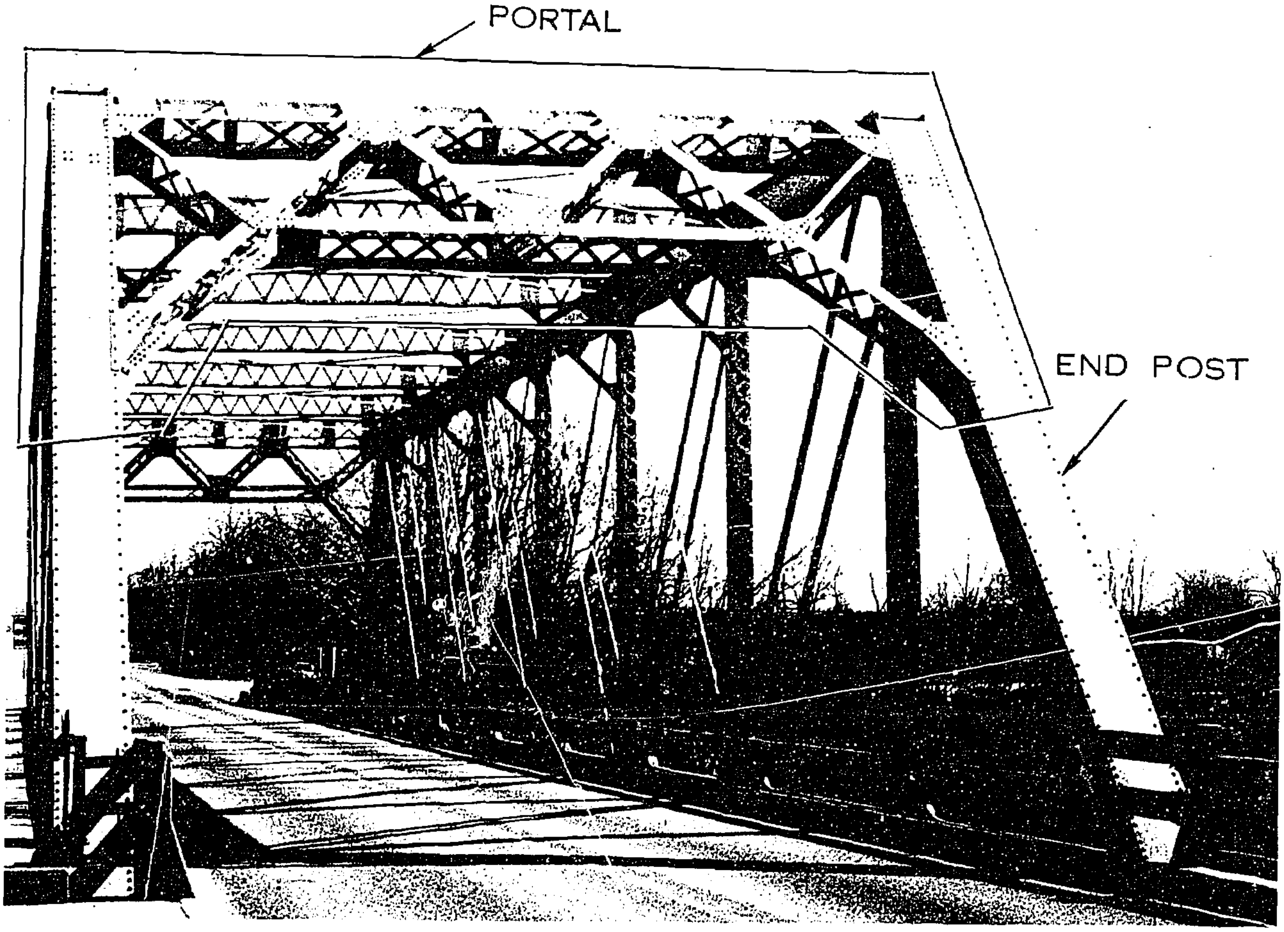



*Figure 5–72. End view of truss showing portal members and end posts.*

## Section 18. METAL BEARINGS

### 5–18.1 General.

Bearings transmit and distribute the superstructure loads to the substructure, and they permit the superstructure to undergo necessary movements without developing harmful overstresses. Bearings are of two general types, fixed and expansion. The principal difference between these bearing types is that fixed bearings resist translation, to permit rotation of the superstructure, while expansion bearings permit both rotation and translation of the superstructure. Except on very short spans, bearings are usually designed to permit small amounts of end rotation. Depending on structural requirements, the bearings may or may not be designed to resist vertical uplift. A number of different types of fixed and expansion bearing devices are used in bridge construction. Typical examples are illustrated in figures 5–73, 5–74, and 5–75.

### 5–18.2 What to Look for During Inspection.

In examining these types of bearings, determine initially whether they are actually performing the functions for which they have been designed. Bearings should be carefully examined after unusual occurrences such as heavy traffic damage, earthquakes or batterings from debris in flood periods. Bearings should be inspected for the following:

a. Check that rockers, pins, and rollers are free of corrosion and debris. Excessive corrosion may cause the bearing to "freeze" or lock and become incapable of movement. When

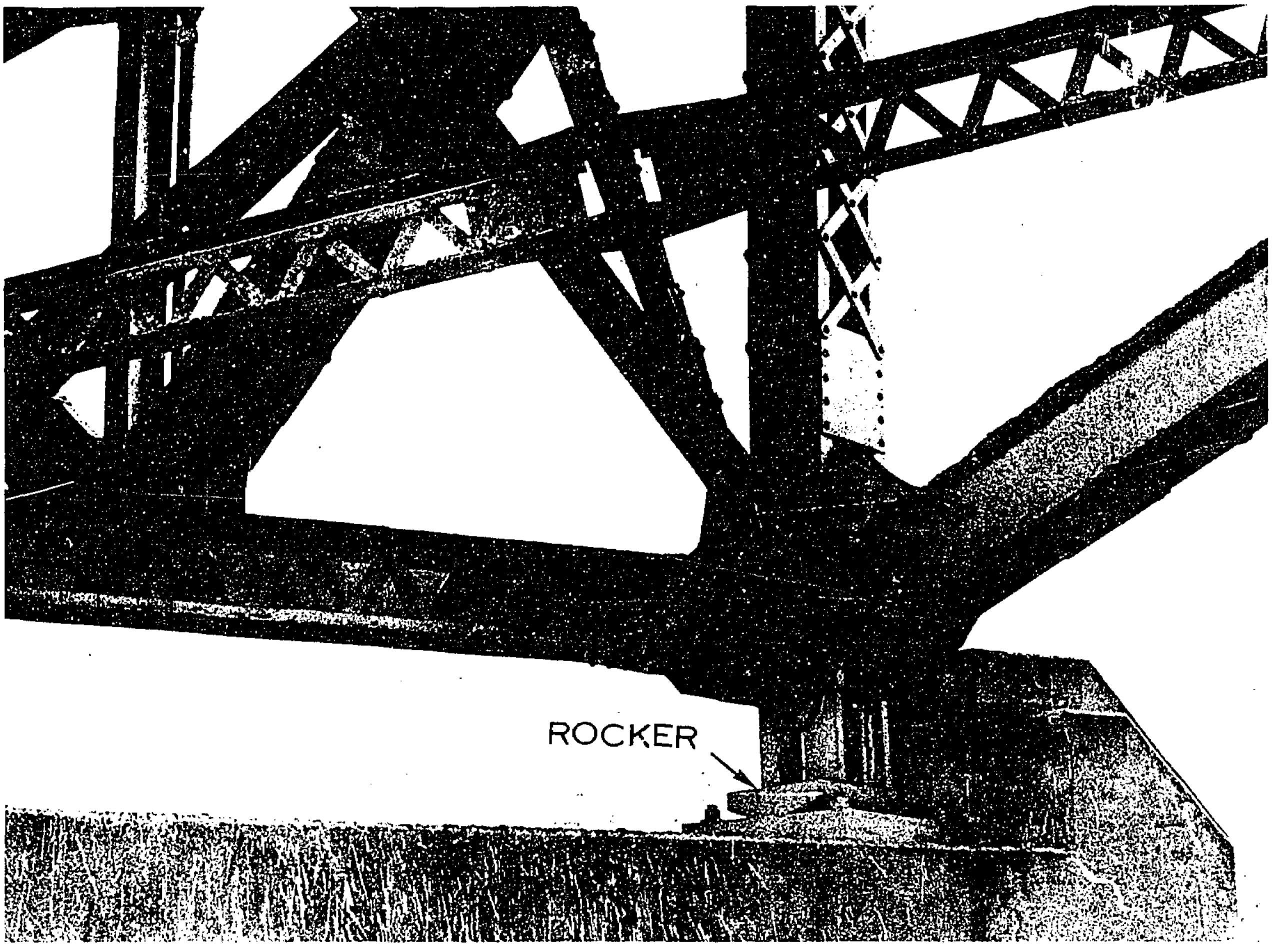



*Figure 5–73. Expansion rocker bearing on pier.*

movement of expansion bearings is inhibited, temperature forces can reach enormous values.

b. Rocker bearings where slots are provided for anchor bolts, should be checked to ensure that the bolt is not frozen to the bearing.

c. Check that the bearing surfaces of rockers and rollers and the deflection slots around pins are clean and free of corrosion.

d. Determine whether the bearings are in proper alignment, in complete contact across the bearings surface, and that the bearing surfaces are clean.

e. Check bearings that require lubricants for proper functioning to ensure adequate and proper lubrication.

f. In those cases where bronze sliding plates (fig. 5–76) are used, look for signs of electrolytic corrosion between the bronze and steel plates. This condition is common on bridges that are located in salt air environments.

g. Detection of bearing rattles under live load conditions usually indicates that the bearings are loose. Determine the cause of this condition.

h. Check anchor bolts for looseness or missing nuts.

i. Measure the rocker tilt to the nearest 1/8″ offset from the reference line as shown in figure 5–77. The appropriate amount of rocker tilt depends upon the temperature at the time of observation. Most rockers are set to be vertical at 68°F for steel bridges. Record the temperature at the time of inspection.

j. Measure the horizontal travel of the sliding bearings to the nearest 1/8 inch from the reference point. The two punch holes are aligned vertically at the standard of temperature used

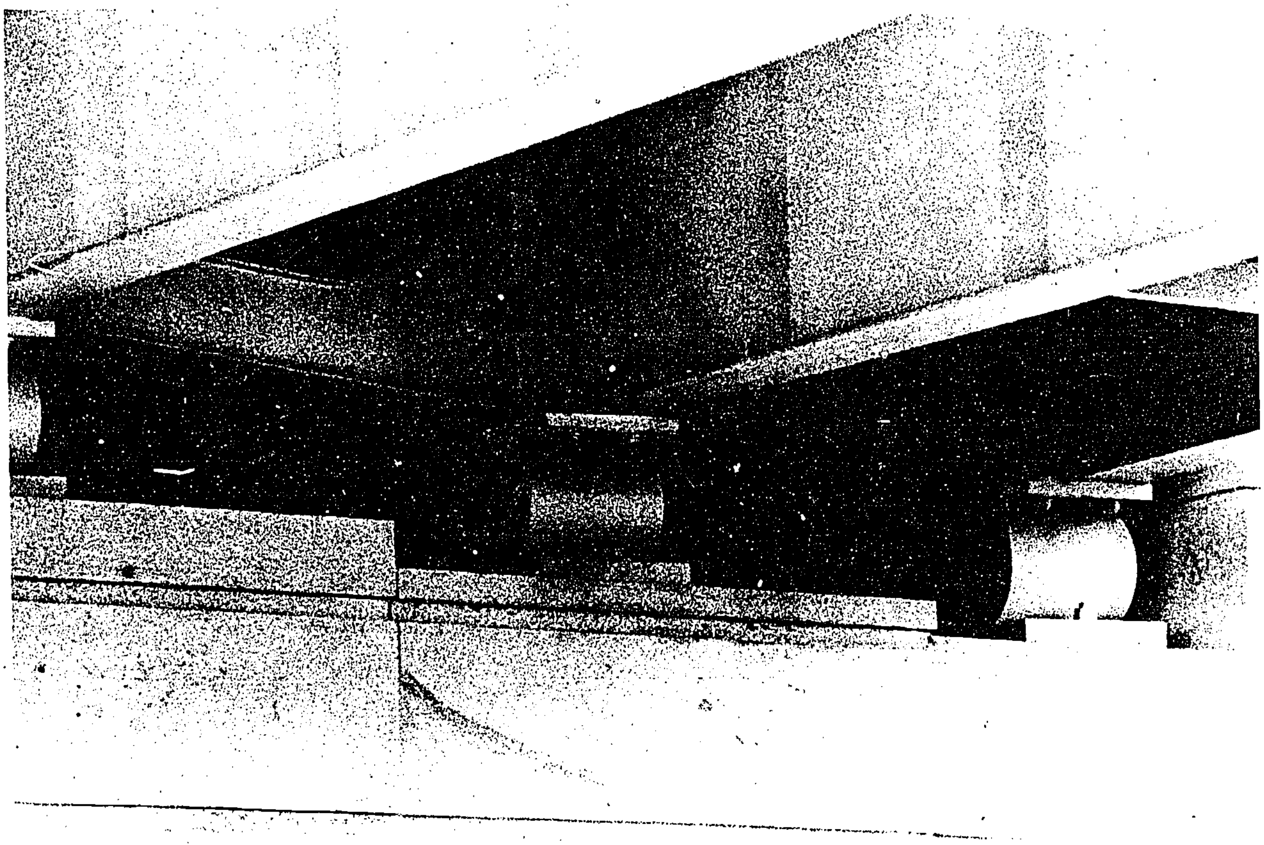


*Figure 5–74. Expansion roller bearings on abutment.*

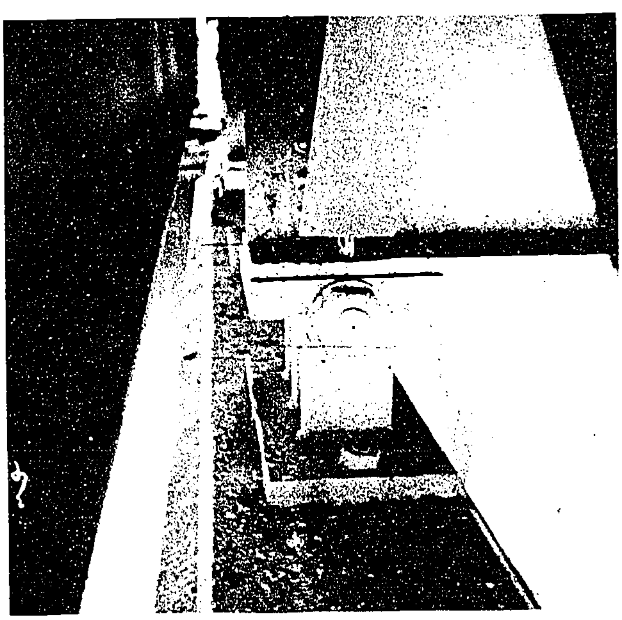


*Figure 5–75. Fixed bearing on pier.*

(usually 68°F). Record the temperature at the time of inspection.

k. On skewed bridges, bearings and lateral shear keys should be checked to determine if either are binding or if they have suffered damage from the creep effect of the bridge.

l. Check cantilever girder hanger connections (fig. 5–78) and pin bearing connections (fig. 5–79) for corrosion and improper alignment.

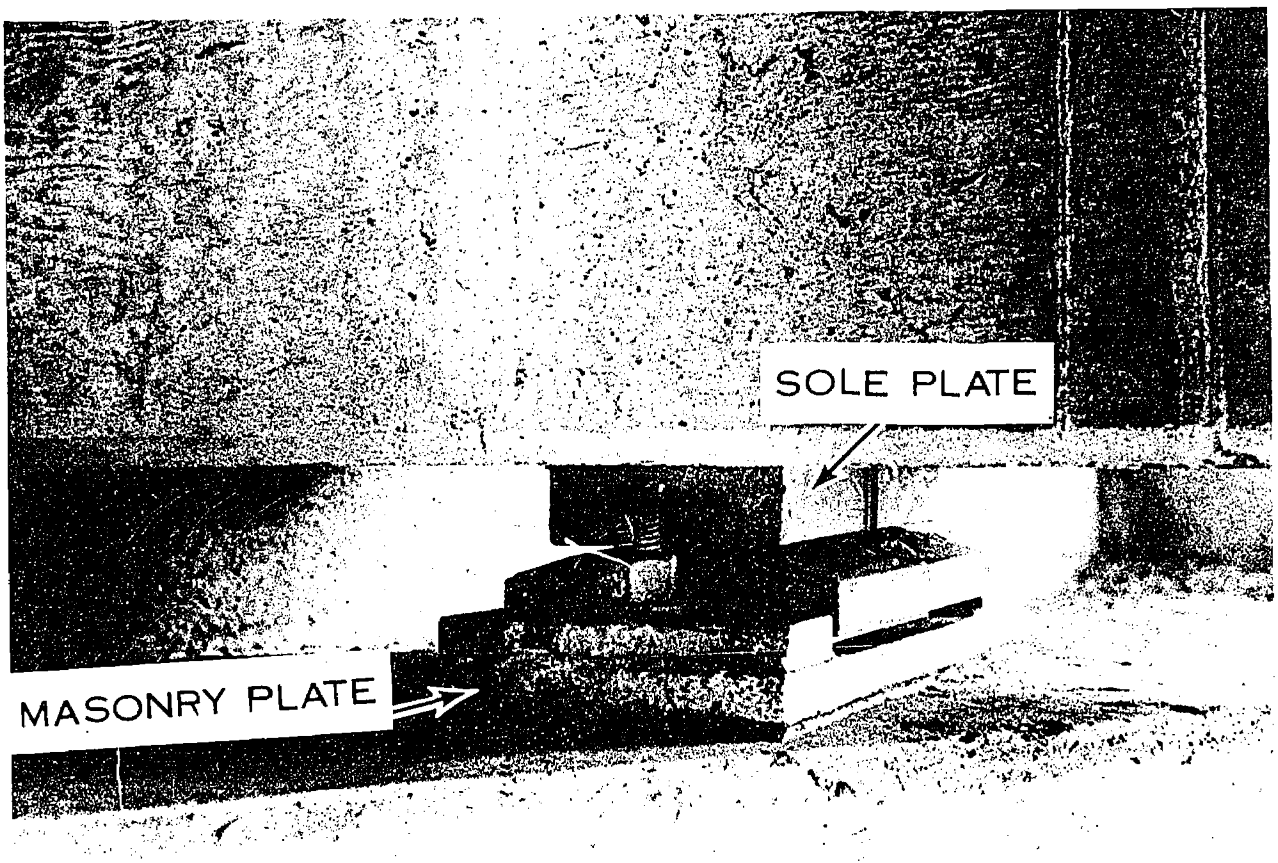



*Figure 5–76. Bronze plate expansion bearing at abutment. The lubricated bronze plate is hidden underneath the curved rocker plate.*

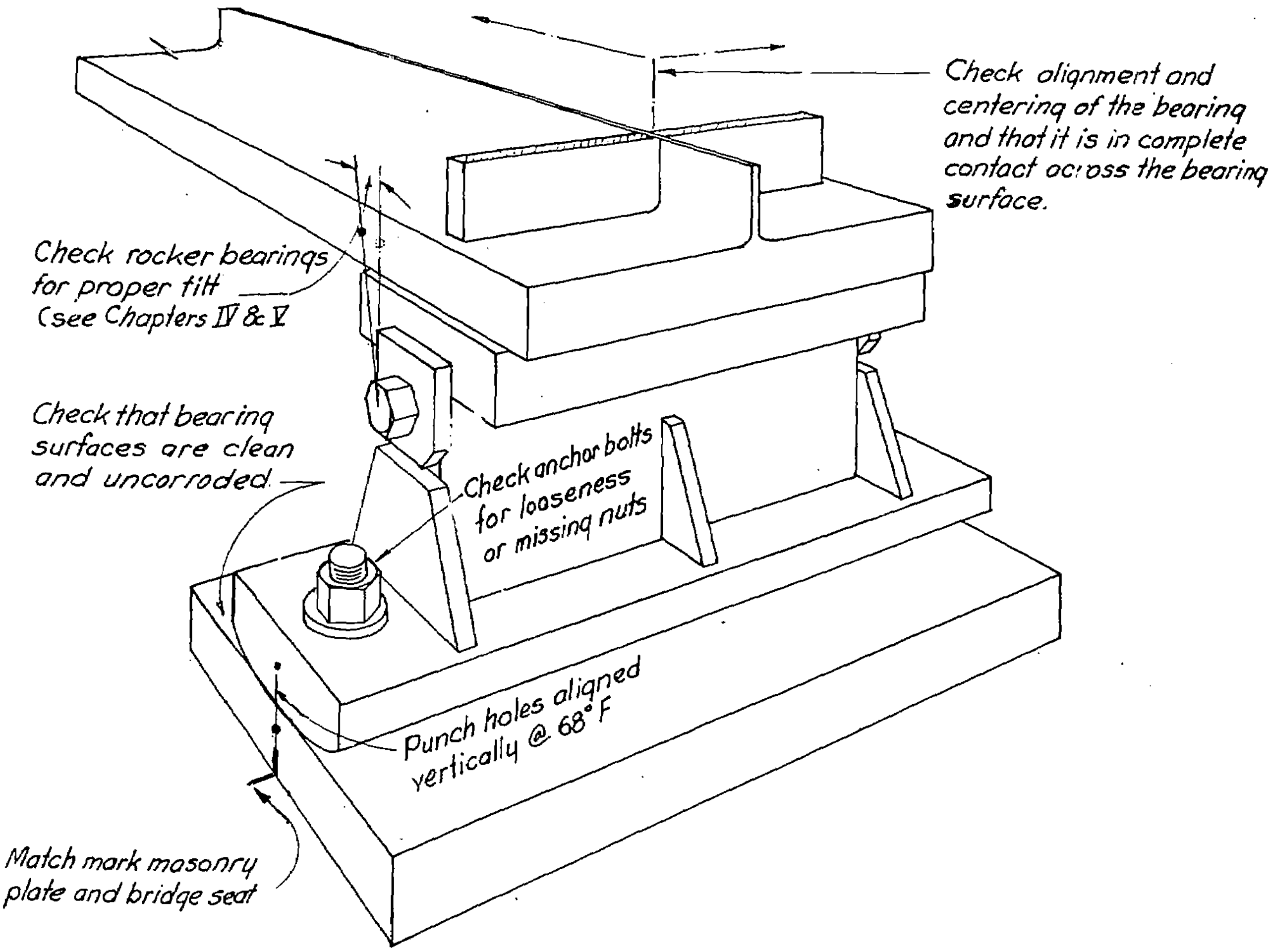



*Figure 5–77. Metal bearing checklist items.*

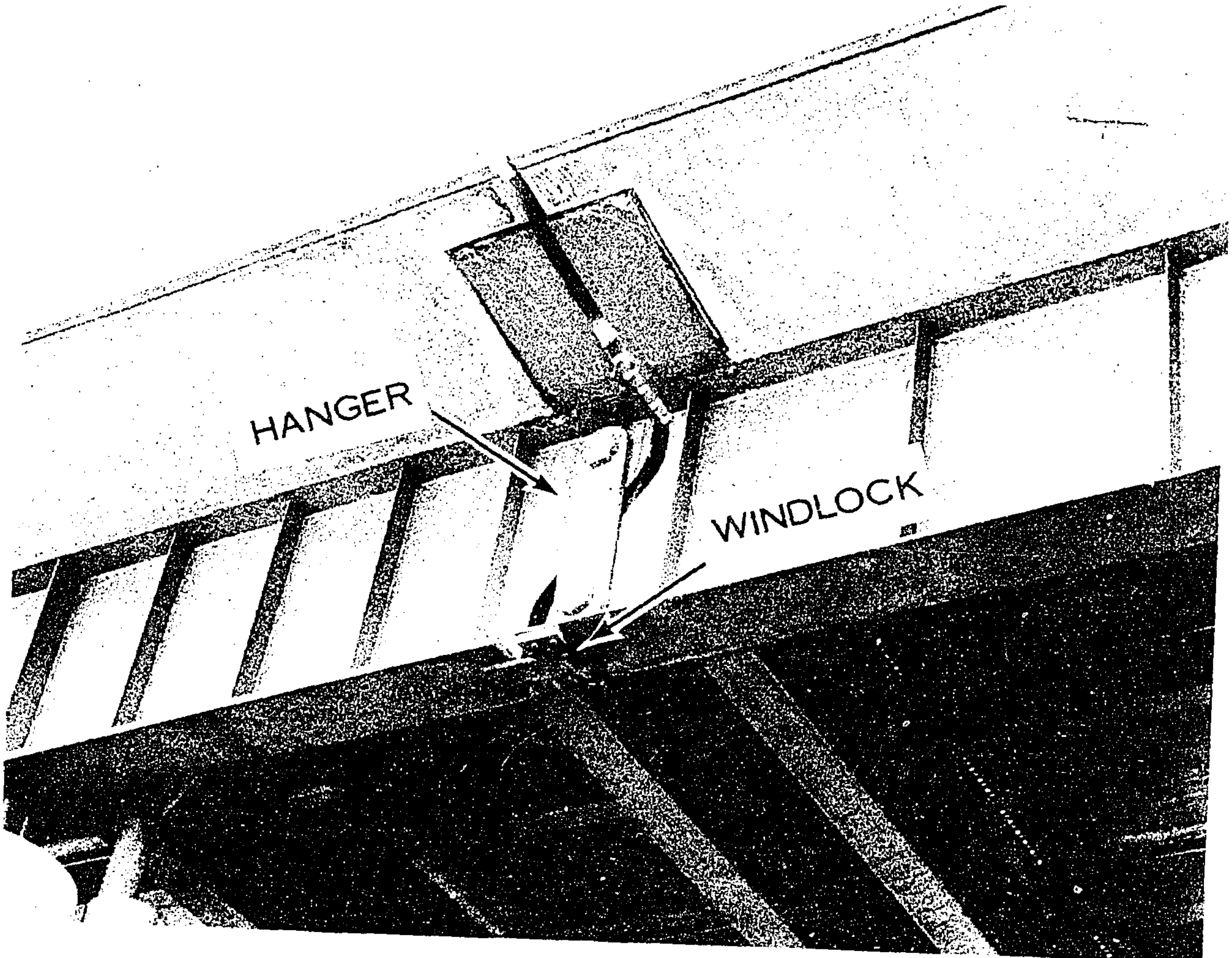



*Figure 5–78. Cantilever girder hanger connection. This type of connection permits both translation and rotation.*

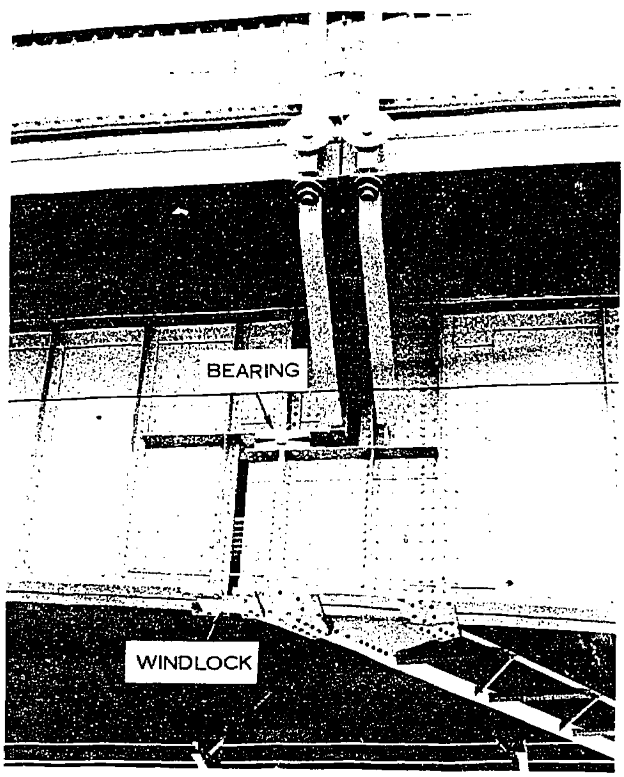



*Figure 5–79. Cantilever girder with direct bearing. Note windlock.*

### Section 19. ELASTOMERIC BEARINGS

5–19.1 General.

a. *Construction.* Elastomeric bearing pads (fig. 5–80) are a type of expansion bearing device. They are made of a rubber-like material or elastomer molded in rectangular pads (fig. 5–81), or in strips.

b. *Function.* When placed beneath a beam they permit moderate longitudinal movements and small rotations at the ends. On longer spans, two or more pads may be laminated with steel plates between the pads to allow for greater movement without excessive bulging around the sides. Longitudinal movement is accomplished by a shearing deformation of the elastomer. The recommended ratio of displacement to pad thickness is 1:4 for single pads. However, using a single pad thick enough to provide for the necessary movement could result in a large lateral or bulging deformation. To avoid this situation, steel plates are bonded between the pads of elastomer, restricting the bulge but permitting slight deformation.

c. *Problems.* Possibly, the greatest problem encountered with elastomeric bearing pads concerns material which does not meet specified requirements. Elastomeric bearing pads of inferior quality may exhibit any of a number of defective signs, such as cracking, splitting, bulging, or tearing. A common defect of poor or improper fabrication results in the top and bottom surface of the pads not being parallel. This condition could result in unequal pressures on the pad. Any of the problems mentioned could result in the pad being unable to perform its design function satisfactorily. Failure of the bearing pad to function properly could lead to deck distress and the transfer of additional and unique forces to the substructure which it may not be able to sustain. After unusual occurrences such as heavy traffic damage, earthquake, or flood, the bearing pads should be examined carefully to assess the effect of such events on the functioning of the pads.

**5–19.2 What to Look for During Inspection.**

a. Splitting or tearing, either vertically or horizontally (fig. 5–82). This is often due to inferior quality pads.

b. Bulging caused by excessive compression which may be the result of poor material composition.

c. Variable thickness other than that which is due to the normal rotation of the bearing.

d. Note the physical condition of the bearing pads and any abnormal flattening which may indicate overloading or excessive unevenness of loading.

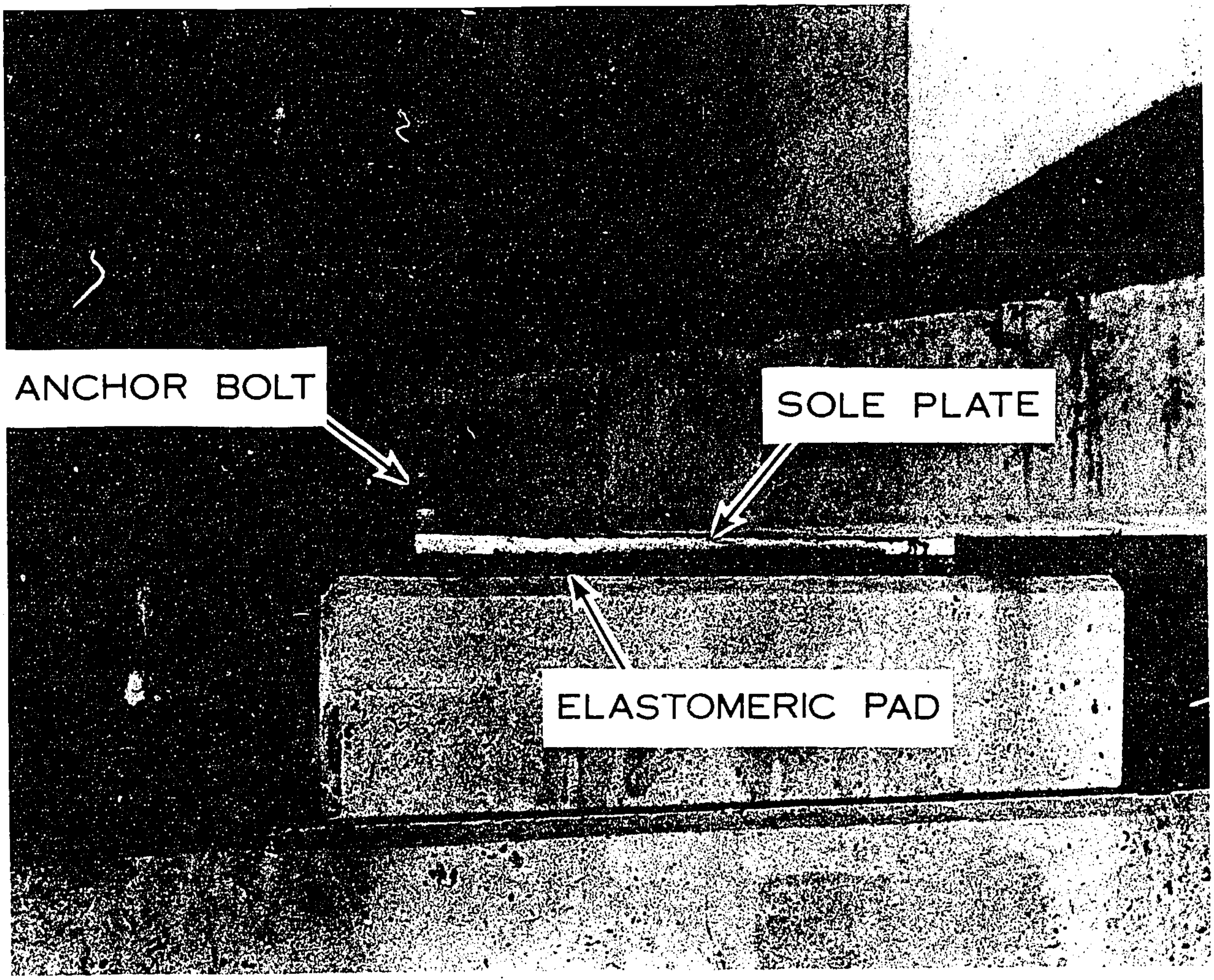



*Figure 5–80. Elastomeric bearing pad. Note steel sole plate.*

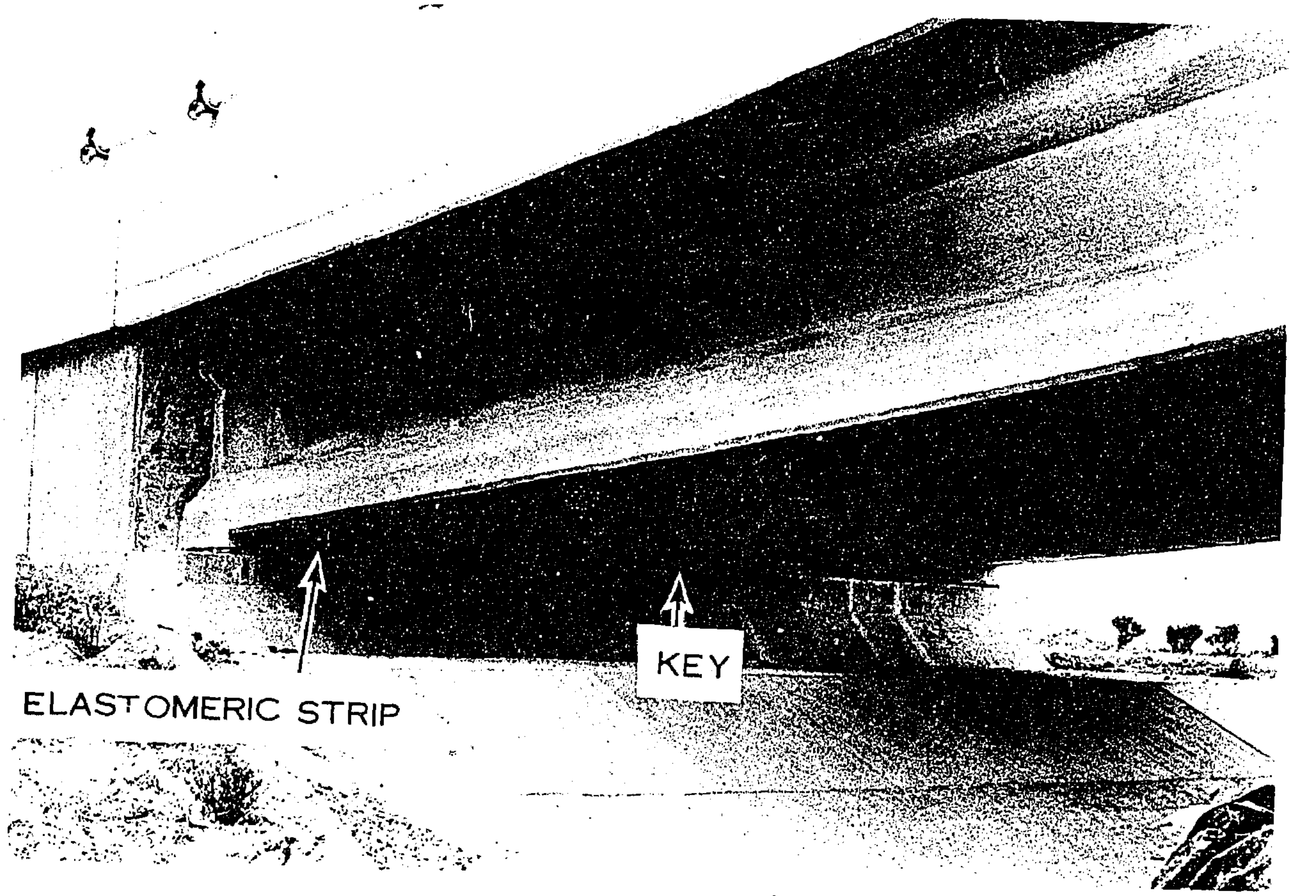
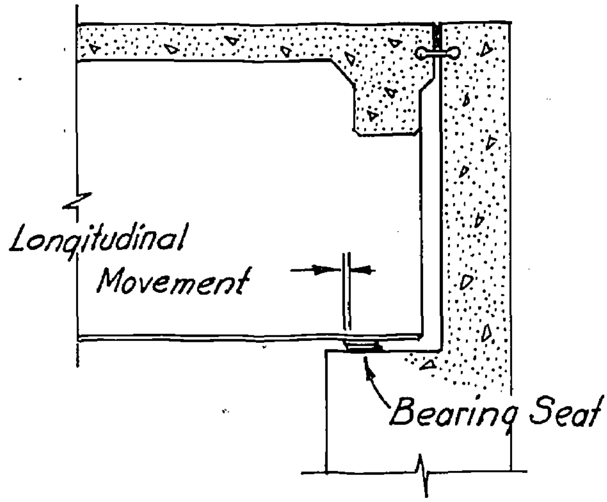



*Figure 5-81. Prestressed concrete bridge on elastomeric bearing pad. Note key to prevent lateral movement.*



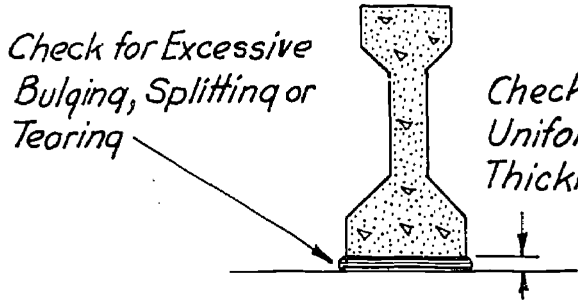



*Figure 5–82. Elastomeric pad checklist items.*

## Section 20. DECKS

### 5–20.1 General.

a. *Function.* The primary functions of the bridge deck are to provide a riding surface for traffic and to transmit wheel loads to the underlying supporting members. On composite bridges, the concrete deck also serves as the top flange of the beams or girders. This is done by placing shear connectors along the interface between the beam and the slab. Steel, prestressed concrete, and timber beams have all been used in composite construction.

b. *Causes of Deterioration.* Probably more than any other part of the bridge, the deck is subject to the adverse effects of traffic, weathering, and chemical action. The repeated use of deicing agents and abrasives on bridge decks is

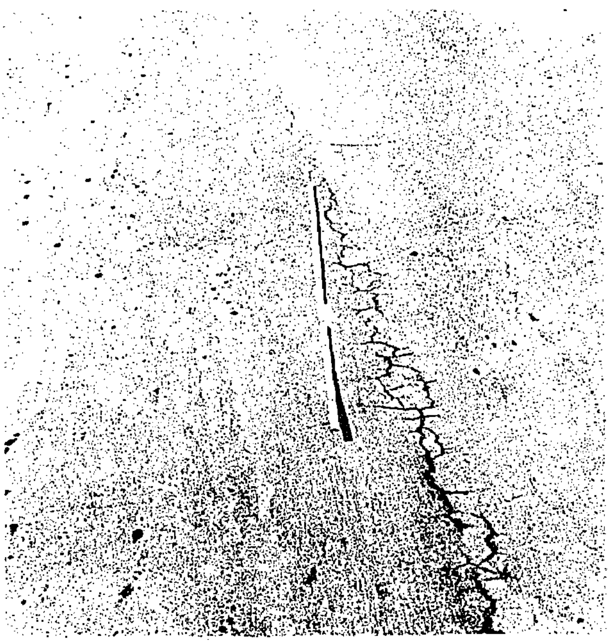


*Figure 5–83. Longitudinal deck crack.*

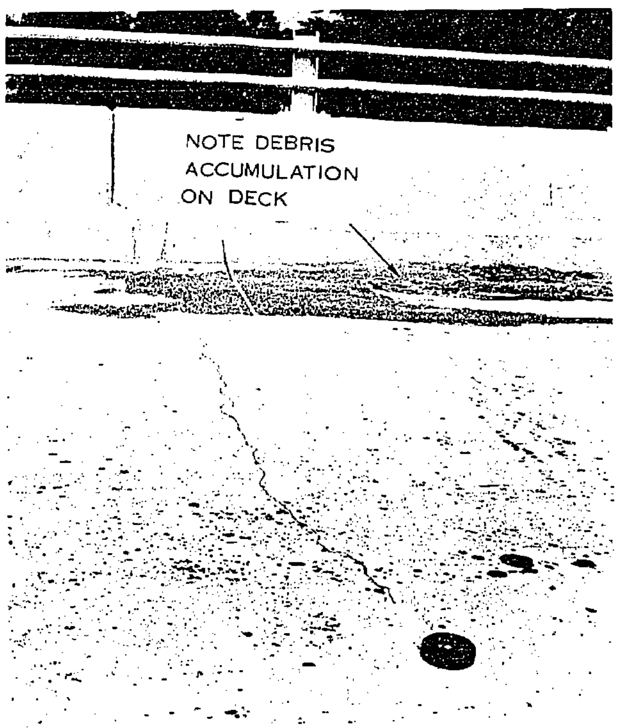



*Figure 5–84. Transverse deck crack. Crack originated at expansion joint in parapet. Note debris in gutter area.*

a major cause of deterioration. Defective materials, inadequate design practices, and improper construction methods also contribute to deterioration. Where the beginning of deterioration is evident, it is important to take early remedial action in order to avoid costly future repairs.

### 5-20.2 What to Look for During Inspection.

a. *Concrete Decks.* Check for cracking, scaling, and spalling of the concrete and record the extent of the deterioration. Refer to Section 5-1 for guidance in describing these conditions.

(1) *Scaling.* Scaling is usually an indication of improper construction techniques or the use of defective material. It may also be the result of inadequate maintenance or inadequate deck drainage.

(2) *Spalling.* The extent of spalling can be determined by tapping lightly with a hammer in the vicinity of the spall. A hollow sound indicates a separation or fracture plane in the concrete beneath the surface. The hollow area should be marked, measured, and recorded. Expansion joints and construction joints should be examined most thoroughly for spalling. In addition to the previously mentioned causes, spalling may be the result of deck or foundation movement. This is a particularly likely cause if the joints are not properly closed.

(3) *Cracking.* While cracking is often due to material or construction defects, other common causes are: foundation movement, pavement thrust, a too-flexible design, failure of the supporting members, abrupt changes in reinforcement, and inadequate design. Figures 5-83, 5-84, and 5-85 show examples of deck cracks.

(a) *Deck Surface.* Note the type, size, and location of cracks in the deck. Refer to Section 5-1 for crack classification.

(b) *Deck Underside.* Inspect the underside of the deck for cracks and water leakage. The passage of water through the deck usually causes some leaching of the concrete which forms grayish-white deposits of calcium hydroxide in the area of the leak. Extensive water leakage may indicate segregated or porous concrete, or a general deterioration of the deck. Areas of wet concrete are additional indications of defective concrete.

(c) *Wearing Surface.* Examine the wearing surface covering the concrete deck for reflection cracking and for poor adherence to the concrete. Deteriorated concrete beneath the wearing surface will often be reflected through

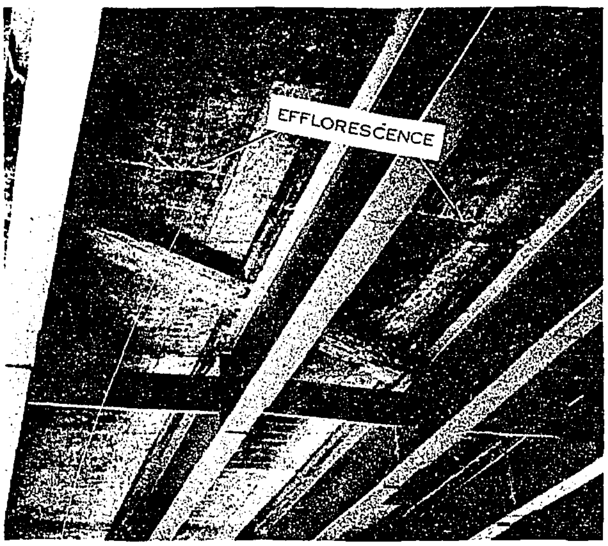



*Figure 5-85. Transverse cracks. Note cracks are near inflection point, and are transverse even though deck is skewed. Note efflorescence.*

*Figure 5-86. Rusted stay-in-place (S-I-P) forms.*

the surface in the form of map cracking. Poor adherence leads to development of potholes. If deterioration is suspected, remove a small section of the wearing surface in order to check the condition of the concrete deck.

(d) *Stay-in-place (S-I-P) Forms.* Remove several panels of the S-I-P forms, if cracking is suspected, to permit examination of the underside of the deck. Rusty forms (fig. 5–86), water dripping from pinholes in the form, or the separation of portions of the forms from the deck are reliable indications of deck cracking.

(e) *Reinforcing Steel.* Note whether there are any stains on the concrete which would indicate that the reinforcing steel is rusting. Note whether any of the reinforcing steel is exposed.

(4) *Wear.* Determine whether the concrete surface is worn or polished. When softer limestone aggregates are used in the concrete, fine aggregates and paste will be worn away, exposing the surface of the coarse aggregates to the polishing action of rubber tires. The resulting slippery surface becomes increasingly hazardous when the surface of the limestone is wet.

b. *Timber Decks.*

(1) *Deterioration.* Check for loose, broken, or worn planks, for loose fasteners, and for presence of decay, particularly at the contact point with the stringer where moisture accumulates. Check asphalt overlays for the presence of potholes and cracking as a result of weak areas in the deck.

(2) Observe the timber deck under passing traffic for looseness or excessive deflection of the members.

(3) *Slipperiness.* Timber decks are sometimes slippery, especially when wet. Observe the traction of vehicles using the bridge for signs of this condition.

(4) *Utilities.* If utilities are supported by the bridge, note the effects on the bridge.

c. *Steel Decks.*

(1) Check for corrosion and cracked welds. Maintenance of an impervious surface over a steel deck is an important safeguard against corrosion of the steel. Check to determine if the deck is securely fastened. Note any broken welds or clips. Determine if there is any loss of section due to rust or wear.

(2) *Slipperiness.* Note whether decks are slippery when wet.

(3) *Utilities.* If utilities are supported by the bridge, note any effect on the bridge.

d. *Open-Grating Decks.*

(1) *Cracks.* Examine the grating, support brackets and stringers for cracking of welds.

(2) *Slipperiness.* Note whether decks are slippery when wet. Small steel studs may be welded to the grating in order to improve traction.

## Section 21. EXPANSION JOINTS

### 5–21.1 General.

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 structures, there is usually sufficient yielding in the foundation to allow the small amount of movement to occur without difficulty. On longer structures, however, specially 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 (fig. 5–87) or a preformed compression seal is inserted. Where traffic is heavy, the unprotected edge of the joint is usually armored with steel angles set in the concrete. When larger movements must be accommodated, a sliding plate or finger plate expansion joint may be used (fig. 5–88). A trough is often provided beneath a finger plate expansion joint to catch water from the roadway.

### 5–21.2 What to Look for During Inspection.

a. Check all expansion joints for freedom of movement, proper clearance, and proper vertical alignment (fig. 5–89). There should be sufficient room for expansion but the joint should not be unduly open. Closed or widely opened joints, or a bump at the back wall can result from substructure movements. The crowding of abutments against the bridge ends is common,

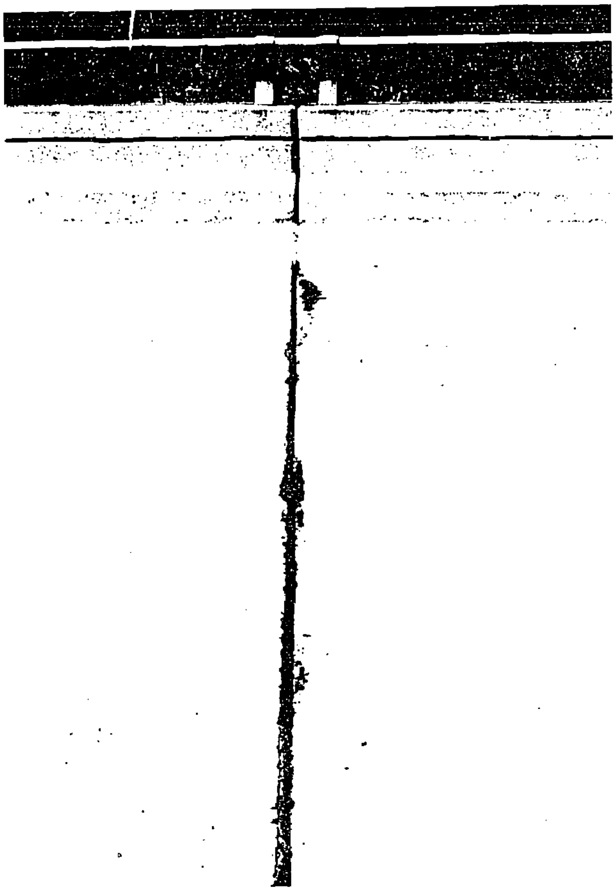


*Figure 5–87. Sealed deck joint. A premolded filler topped with a poured-in-place sealer has been used.*

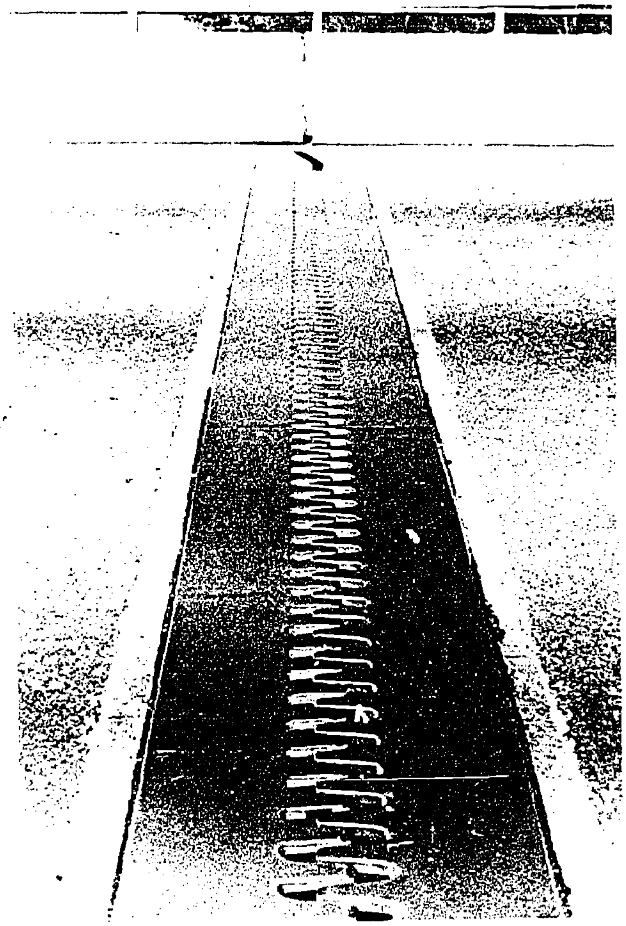


*Figure 5–88. Finger plate expansion device.*

and can cause severe damage to the bridge. Proper opening size depends on the season, the type of joint seals, the temperature range, and the length of the slab whose expansion the joint must accommodate. Normal temperature is usually assumed to be 65° to 70°F. Table 5–1 lists some general data for various types of expansion joints. The expansion length in table 5–1 is the portion of deck or structure whose expansion must be accommodated by the joints. This distance may extend from the end of the bridge to the nearest fixed bearing, or it may be the sum of the distance on both sides of the joint. Multiplying the expansion length by the differential between the temperature at the particular moment and 68°F, and this product by 0.0000065 will give the approximate change in joint openings from the values listed above. Very often, construction plans will give useful data concerning the setting of expansion devices.

b. Check seals for water tightness and general conditions. Look for:

(1) Seal or sealant pulling away from the edges of the joints.

(2) Abrasion, shriveling, or other physical deterioration of the seal.

(3) Stains and other signs of leakage underneath the deck. Leaking seals permit water and brine to flow onto the bridge seat and pier cap causing corrosion of bearings, disintegration of concrete, and staining. Joints not properly sealed should be cleaned and resealed.

c. Check to see that expansion joints are free of stones and other debris. Stones lodged in the joints can create localized stresses which may cause cracking and spalling of the deck. Large amounts of debris cause jamming, thus rendering the joints ineffective.

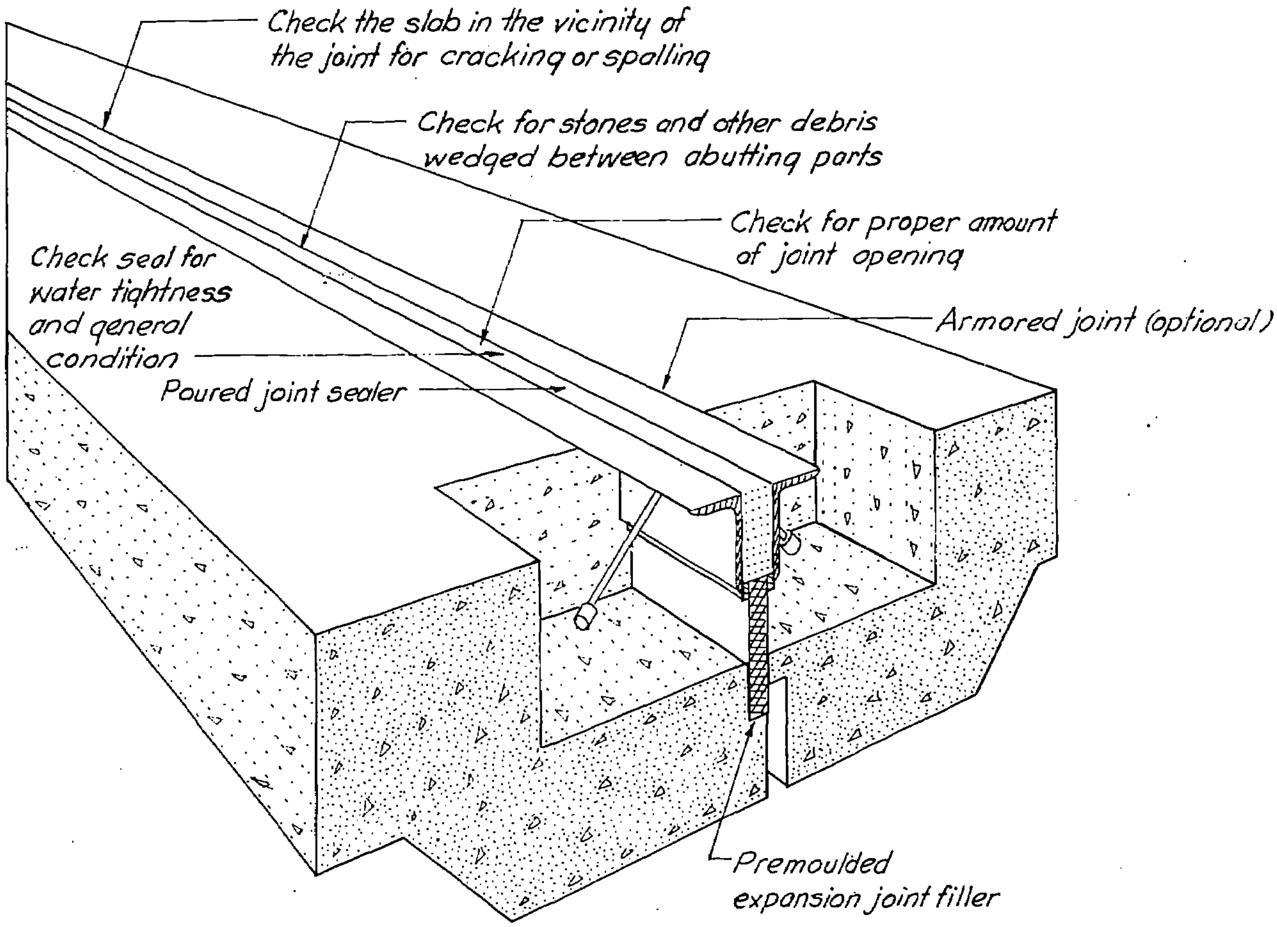



*Figure 5–89. Expansion joint checklist items.*

Table 5–1. Expansion joint data.

| *Joints* | *Expansion Lengths* | *Joint Openings at 68°F.* |
|---|---|---|
| Steel finger dams | 200 feet or more | 3 inches min. |
| Steel expansion plates | 200 feet maximum | 2 inches |
| Compression seals | 135 feet maximum | 1⅝ inches |
| Poured sealants and joint fillers | 120 feet maximum | 1½ inches |

d. Examine steel finger type joints and sliding plate joints for evidence of loose anchorages, cracking or breaking of welds, or other defective details. Sometimes the fingers may be damaged by traffic or by cracks which have developed at the base of the fingers.

e. Verify that surfacing material has not jammed the finger joints on bridges that have been resurfaced several times.

f. Examine specifically the underside of the expansion joint, regardless of accessibility, to detect any existing or potential problem.

g. Sound the concrete deck adjacent to all expansion devices for voids or laminations in the deck.

## Section 22. RAILINGS, SIDEWALKS, AND CURBS

### 5–22.1 General.

Railings, sidewalks, and curbs normally do not contribute to the structural strength of the bridge. They are provided mainly for public safety.

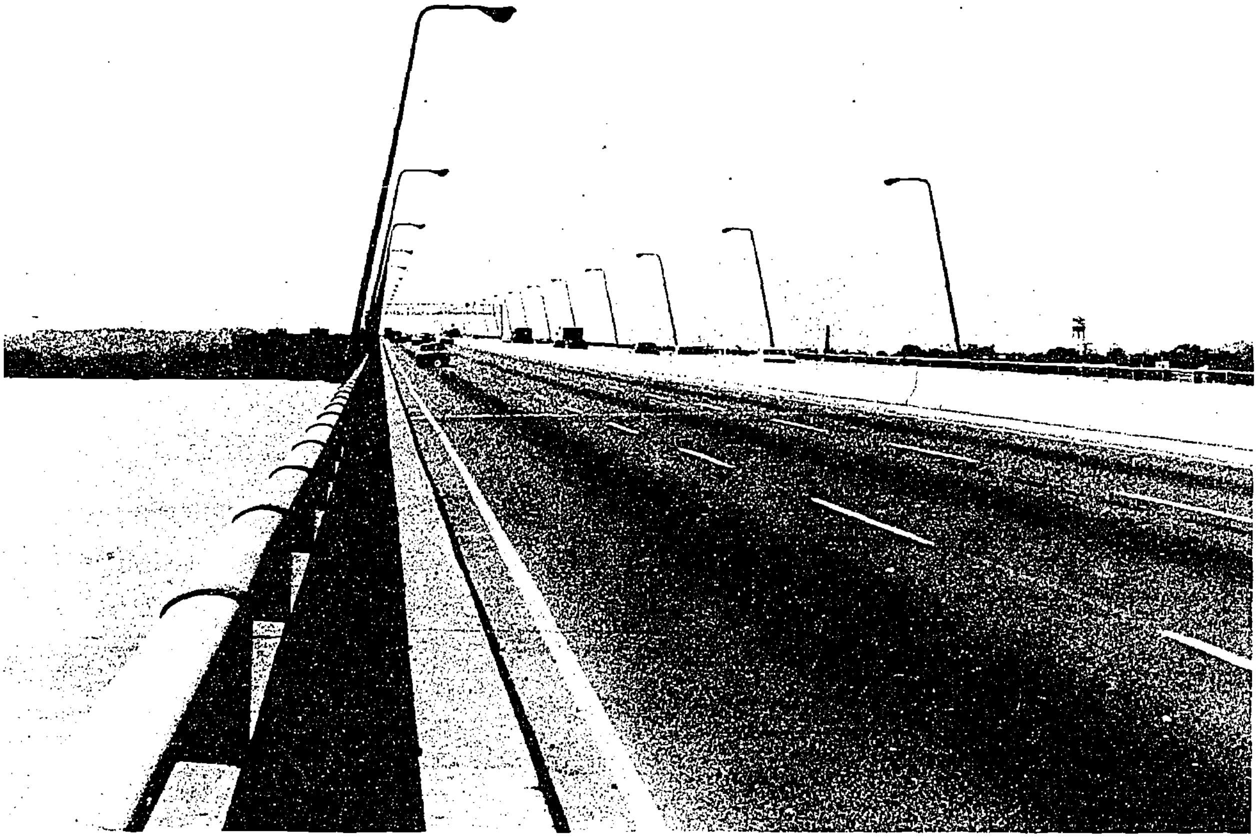


*Figure 5–90. Concrete parapet and sidewalk with steel tubular rail (left) and concrete median barrier (right).*

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 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. *Narrow Roadway.* Bridge roadways that are narrower than the approach roadway are dangerous since they restrict vehicular maneuverability and can be the cause of accidents.

c. *Sidewalks and Curbs.* Sidewalks and curbs (fig. 5–90) are provided to protect pedestrians crossing the bridge. In rural areas, often only a narrow curb is provided (fig. 5–91).

**5–22.2 What to Look for During Inspection.**

a. *Railings.*

(1) Inspect all railings for damage caused by collision, and for weakening caused by some form of deterioration.

(2) Check concrete railings for cracking, disintegration, and corrosion of rebars.

(3) Check steel and aluminum railings for loose posts or rails, and for rust and other deterioration. In particular, check the condition of the connections of the posts to the decks, including the condition of the anchor bolts and the deck area around them.

(4) Check timber railings for decay, loose connections, and for missing or damaged rails.

(5) Check the vertical and horizontal alignment of all handrails for any indications of settlement in the substructure or any bearing deficiencies.

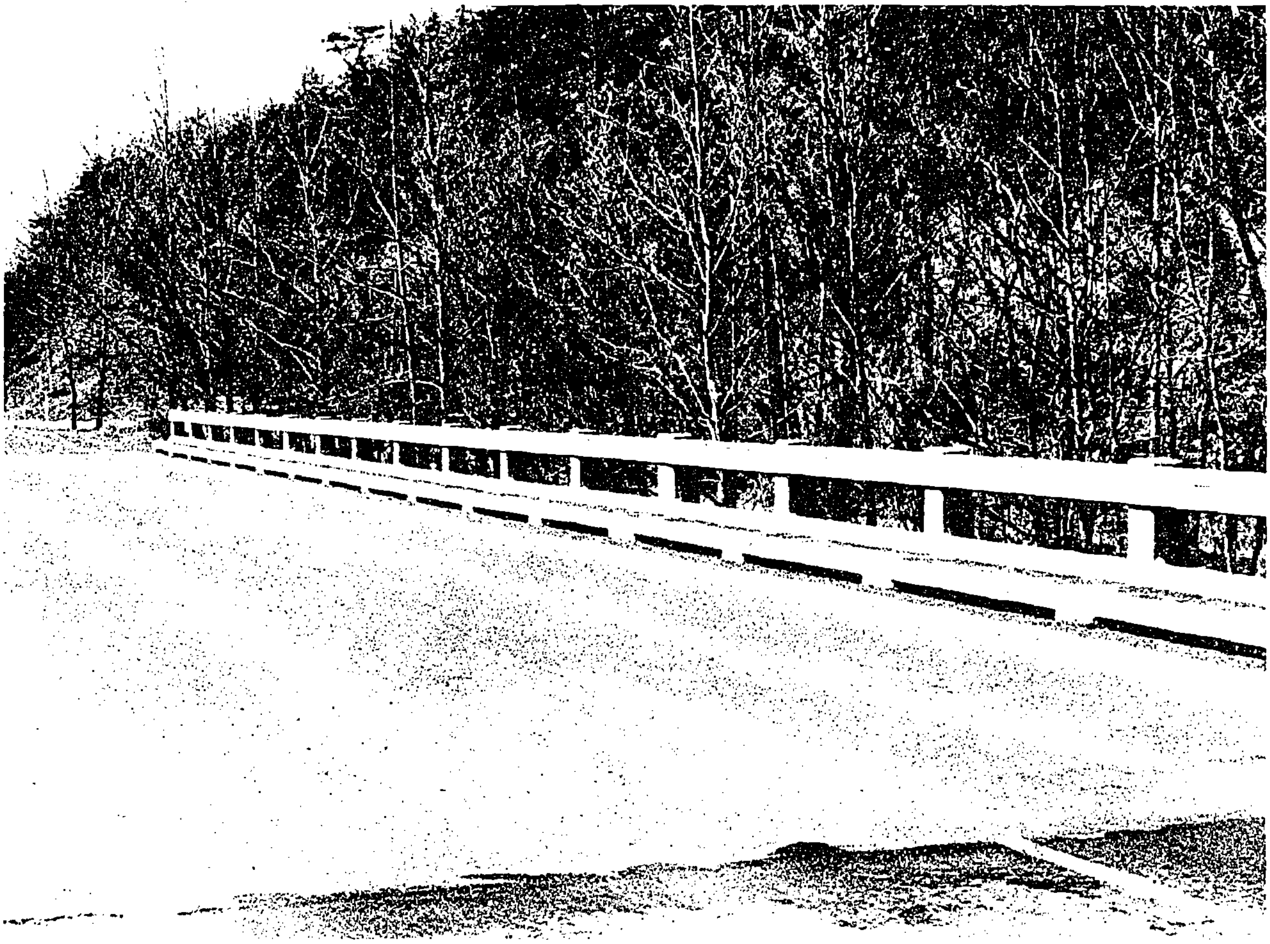


*Figure 5–91. Concrete railing and curb.*

(6) Examine all handrail joints to see that they are open and functioning properly.

(7) Examine all handrails to see that they are of adequate height, secure, and relatively free of slivers or any projections which would be hazardous to pedestrians.

(8) Check for rust stains on the concrete around the perimeter of steel rail posts which are set in pockets. Remove grout from around the posts and determine severity of corrosion if rust stains indicate such action is warranted.

(9) Note whether barrier railings on the approaches to bridges extend beyond the end of the bridge railing or parapet end and are anchored to the inside face. This feature reduces the severity of vehicle collision. In situations when parapet ends are unprotected (fig. 5–95), and no approach rail exists, a flared, tapered approach railing should be installed. On two-way bridges, this type of railing should be installed at both ends of the existing railings or parapets.

(10) Examine barrier railings for traffic damage and alignment.

(11) Check concrete barrier railings for cracks, spalls, and other deterioration.

(12) Check for corrosion in the metal portions of barrier railings and determine whether the anchor bolts and nuts are tight.

b. *Sidewalks.*

(1) Check concrete sidewalks and parapets in the same manner as the bridge decks for cracks (figs. 5–92, 5–93, and 5–94), spalls, and other deterioration.

(2) Examine the condition of concrete sidewalks at joints, especially at the abutments, for signs of differential movement which could open the joint.

(3) Check steel sidewalks for corrosion and to see that all connections are secure.

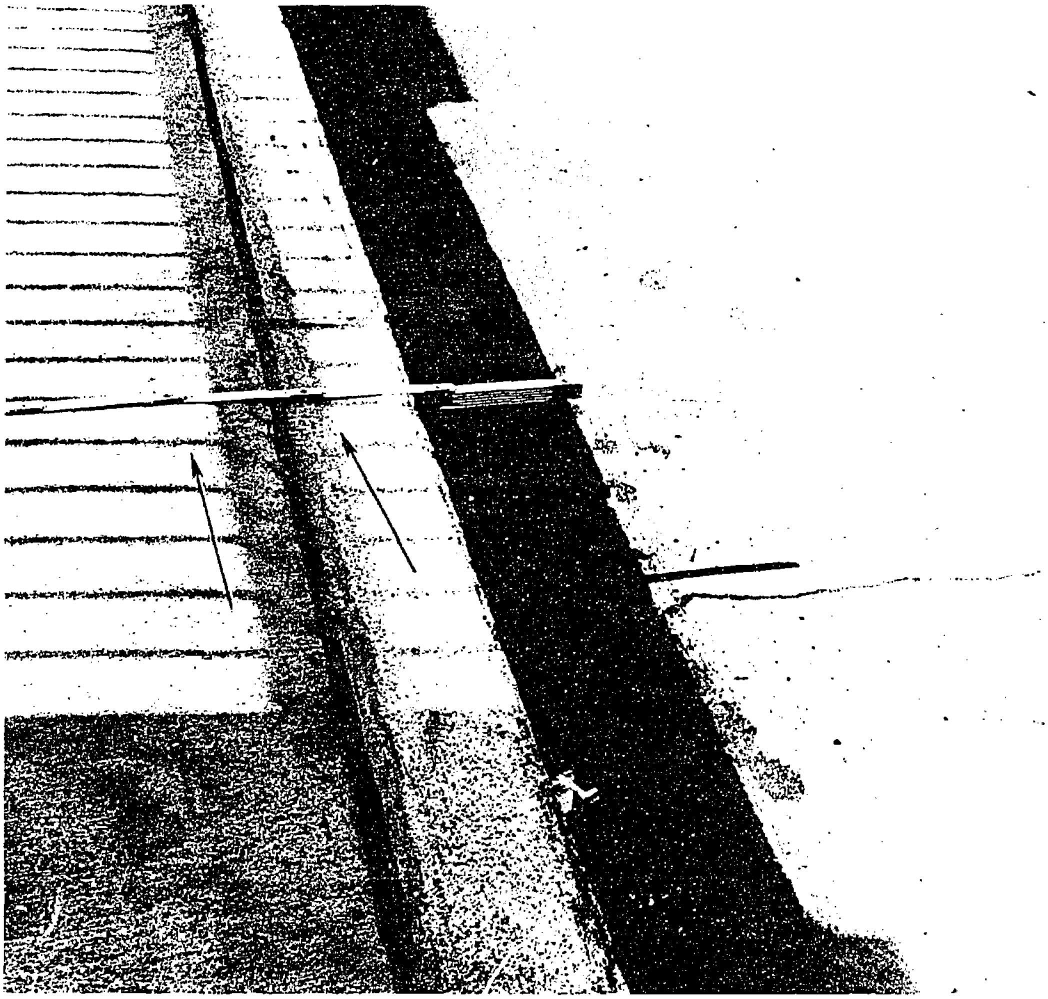


*Figure 5–92. Transverse crack in sidewalk curb and deck. Note that crack extends through the granite curb.*

(4) Check timber sidewalks for soundness of the timber. Determine whether the floor planks are adequately supported.

(5) Check timber sidewalks for hazards to pedestrians such as loose or missing planks, large cracks, decay or warping of the planks, protruding nails, or other hazardous conditions.

(6) Check slickness of surfaced timber during wet or frosty weather conditions to determine whether any corrective action is necessary.

(7) Check sidewalk drainage for adequate carry-off. Examine the sidewalk surface for roughness or other conditions that may make walking hazardous or difficult.

(8) Check structural integrity of sidewalk brackets.

c. *Curbs.*

(1) Check concrete curbs for cracks (figs. 5–92, 5–93, and 5–94), spalls, and other deterioration.

(2) Check timber curbs for splitting, warping, and decay.

(3) Report any curbs or safety walks which project into the roadway, or a narrow shoulder of the roadway, since they are safety hazards.

(4) Note any loss of curb height resulting from the build-up of the deck surface.

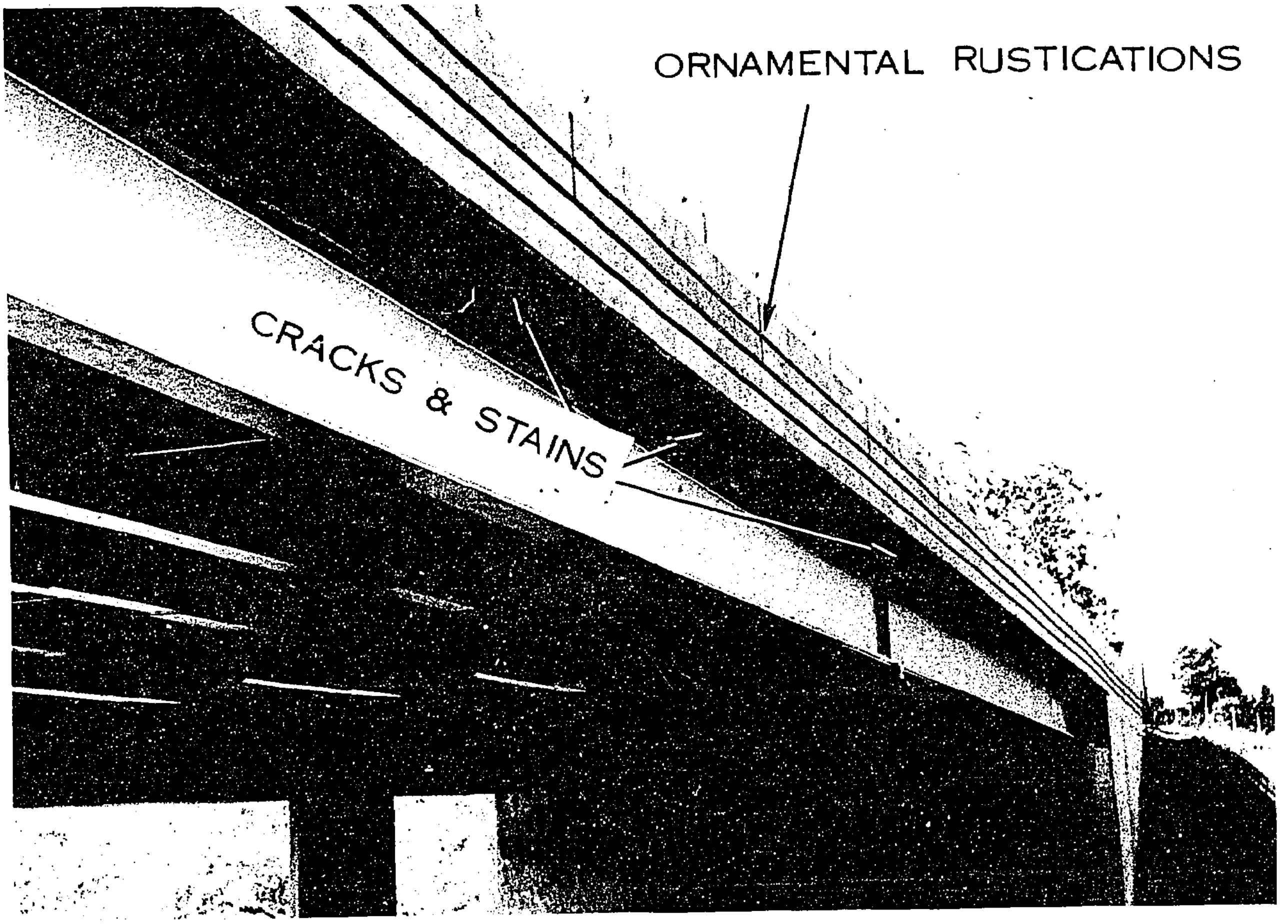



*Figure 5–93. Cracks in sidewalk. Note crack going through slab and note efflorescence stains.*

(5) Examine timber wheel guards including scupper blocks for splits, checks, and decay.

(6) Check timber wheel guards to see whether they are bolted securely in place.

(7) Note condition of the painting of timber wheel guards where paint is used to improve visibility.

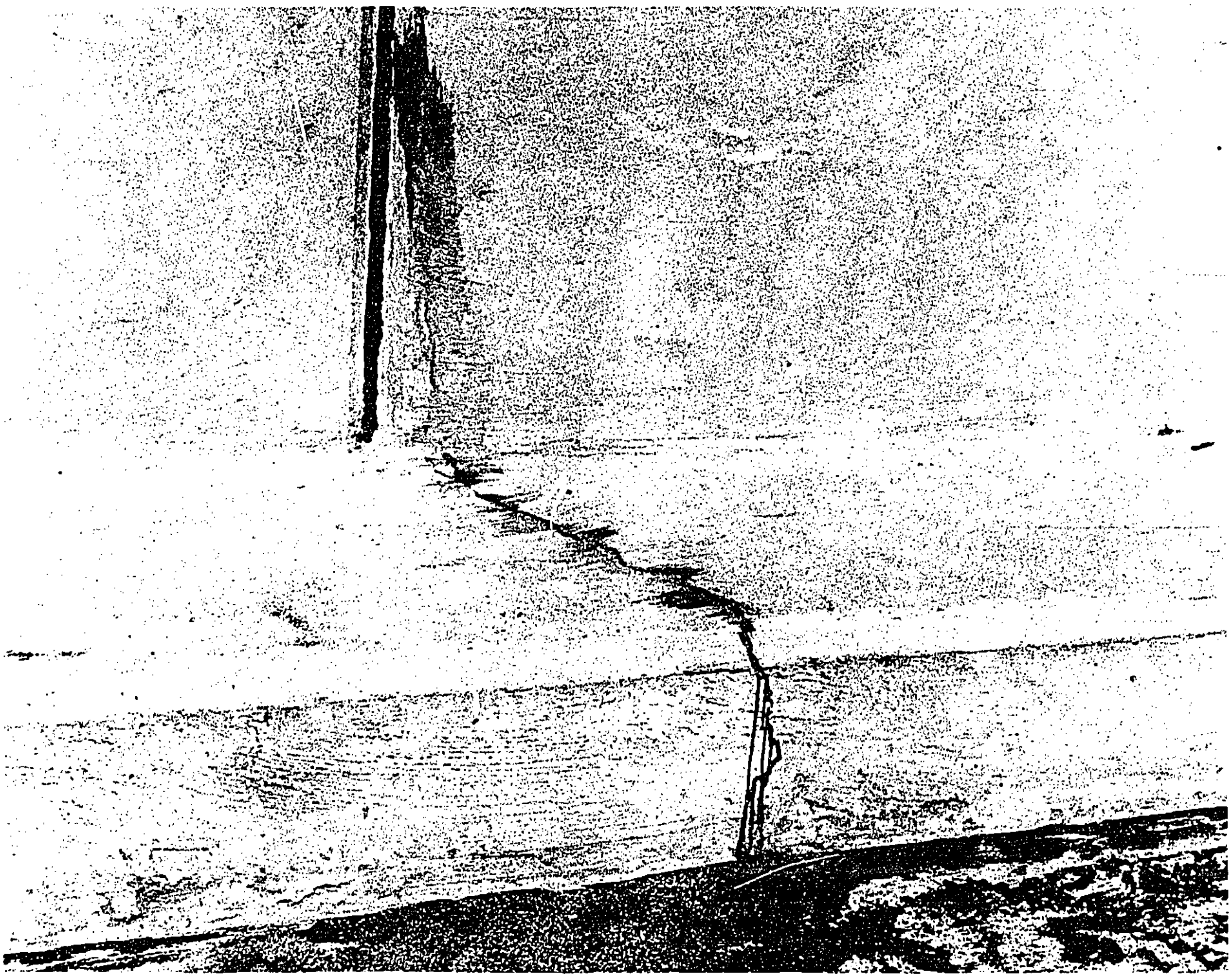


*Figure 5–94. Crack through safety curb. Crack started at parapet joint and continued across curb and deck. See also figure 5–84.*

## Section 23. APPROACHES

### 5–23.1 General.

a. *Elevation Difference.* A smooth transition between the roadway pavement and the bridge deck is important for the reduction of impact forces acting upon the bridge for safety, and for driver comfort. A difference in elevation between the bridge deck and the approach pavement increases impact and vibration as the vehicle reaches the bridge. Rough approaches will also cause vibration in the vehicle which, in turn, transmits added vibration to the bridge. rough approaches are usually the result of a volume change either from settlement in the backfill material (resulting from inadequate compaction) or from a general consolidation of subsoil and approach fills, while the bridge, supported on piles, does not settle at all. In either case, periodic resurfacing may be necessary. One popular solution to this problem is the approach slab which spans the 15 to 25 feet of fill immediately behind the abutment. This minimizes the effects of approach fill settlement and poor compaction.

b. *Joint Width.* The width of the joint at the backwall (or at the other end of the approach slab) is also important. An abnormally closed joint may indicate pavement thrust developing against the backwall. Pavement thrust is often caused by pebbles or debris filling pavement joints after contraction, thereby preventing the joint from absorbing expansion. This causes the total pavement length to increase and, eventu-


*Figure 5–95. Sealed joints at bridge end between abutment backwall and adjacent deck and approach slab.*

ally, press against the bridge. If permitted to persist, such a condition could lead to cracked backwalls, spalling of the abutment face in front of the beam bearing anchor bolts, tipping of piers, and arching of the slab above the beam. A closed joint could also indicate a backward tipping of the abutment due to subsoil settlement. On the other hand, an abnormally wide joint may indicate forward movement of the abutment due to a movement of the supporting soil or bending of piles under lateral earth pressures. This can easily occur under older spill-through type abutments. See Abutments, Railings, Signing, Bridge Drainage, and Foundation Movements for other discussion of defects which indirectly affect approaches.

**5–23.2 What to Look for During Inspection.**

a. *At the Joint of the Bridge Backwall.*

(1) *Vertical Displacement.* Laying a straight edge across the joint will record any differences in elevation across the joint not caused by the grade. If the deck is lower than the approach, or if the straight edge indicates a rotation, then foundation settlement or movement may have occurred, and other indications of such action should be checked.

(2) *Joint Width (Horizontal Displacement).*

(a) *Incorrect Opening.* Measure the joint width for either increased or decreased openings. Either condition indicates foundation movement. A decreased opening could also be caused by pavement thrust. Other parts of the bridge affected by such occurrences should also be investigated.

(b) *Clogged Joints.* Where joints are clogged or jammed with stones and hard debris, the expansion joints will be unable to function properly, and pavement thrust will develop. Make particular note of this condition.

(c) *Joint Seal.* The integrity of the joint sealant (fig. 5–95) is critical to protecting the soil or portions of the bridge under the joint, particularly the bridge seat, from water. The seal may be damaged by either weathering, traffic abrasion, or movement of the seal itself.

b. *Other Transverse Joints Near the Bridge.* Examine these joints for closing or clogging, since they are liable to the same difficulties as the backwall joints. The inspector should note the relative movements (if any) of the joints, any clogging with stones or other debris, and any failure, deterioration, or slippage of the joint seal. The extent of these defects should be reported.

c. *Approach Slabs.* Check for cracking or tipping of the approach slabs. These are indications of poor backfill compaction (although, on a skewed bridge, it would not be unusual for an acute corner to crack).

d. *Shoulders and Drainage.* Check the shoulders and determine whether they are maintained at the same height as the pavement. There should be adequate provisions to carry off drainage in catch basins or ditches, especially if water is allowed to flow off the bridge deck.

e. *Approach Slopes.* Check the approach slopes for adequacy and report any condition which impairs their design function.

f. *Pavement Approaches*. Report any potholes, severe cracks, surface unevenness, or other surface defects that make the approach unusually rough or indicate approach settlement.

### *Section 24. BRIDGE DRAINAGE*

5–24.1 General.

Bridge drainage is an important inspection item 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 (fig. 5–96).

5–24.2 Drainage Problems.

Almost all of the drainage problems encountered by an inspector are caused by the failure of the drainage system to carry water away.

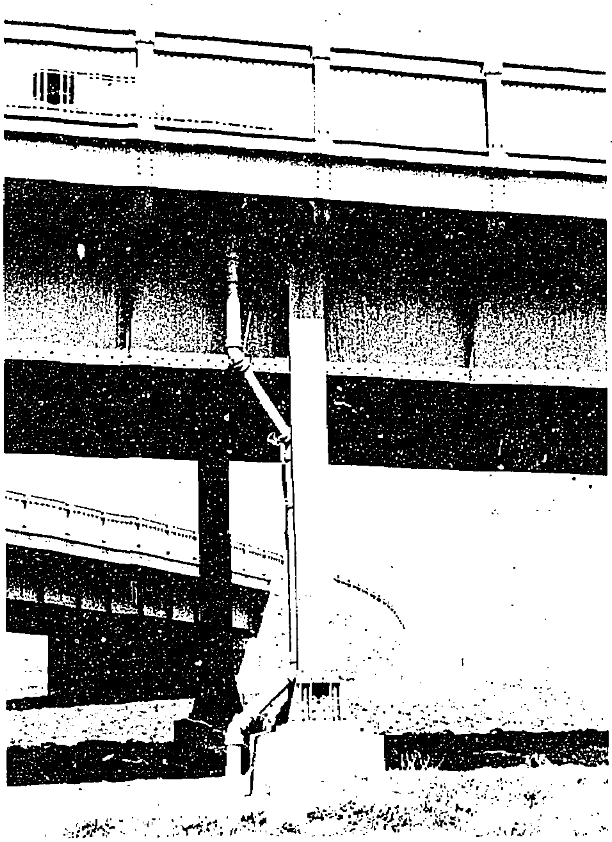


*Figure 5–96. Deck drainage.*

Poor deck drainage usually leads to deck disintegration.

a. *Clogging*. Clogging is the most apparent problem. Clogging occurs at:

(1) *Inlets*. Debris and design oversights are principal causes for inlet clogging. The

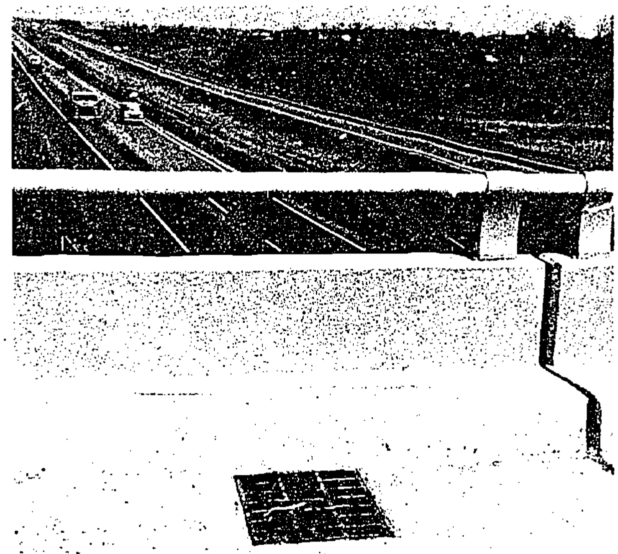


*Figure 5–97. Roadway drain.*

*Figure 5–98. Open pipe drain.*

ponds, or puddles of water, that form on the bridge deck pose the problems of hydroplaning and icing. Ponds, or puddles, constitute a safety hazard and can cause extensive bridge deterioration. Figures 5–97 and 5–98 show two types of inlets.

(2) *Downspouts.* Downspouts and horizontal runs which are poorly designed with inadequate slopes and sharp directional changes at the elbows are conducive to the plugging of drains.

(3) *Expansion Dams.* The gutters under expansion dams fill up very rapidly, especially where roads are heavily sanded in winter. This causes the storm water to overflow onto the bearings, end diaphragms, pier caps, and bridge seats, resulting in severe rusting of the steel and deterioration of the concrete. Of special consequence is the deterioration and freezing of expansion bearings and rollers.

b. *Corrosion.* Drainage water often carries corrosive elements, particularly salt, that attack drainage pipes and concrete. Clogging and slow drainage accelerate corrosion.

c. *Freezing.* Water backed up in the drainage pipes may freeze and, possibly, rupture the pipe. Where the pipe is cast into a pier or abutment, the concrete member may also crack.

d. *Entrapped Water.* Where a concrete deck is covered with an asphaltic wearing surface, the underlying concrete surface is liable to serious deterioration by entrapped water. On some bridges drains have been placed under the wearing surface to avoid this situation.

e. *Short Scupper Pipes.* On river bridges, scuppers usually drain water directly into the river. Where the discharge pipes are short or nonexistent, drainage may splash or blow onto bridge members, causing corrosion.

### 5–24.3 What to Look for During Inspection.

a. *Clogging or Inadequate Drainage Openings.* Check the deck and the deck inlets for signs of clogging or inadequate drainage openings. These deficiencies will be manifested by debris on, or around, the inlet after a storm. Scaling and concrete deterioration around the inlet are additional signs of an inadequate inlet.

b. *Water Stains.* Observe the bridge beams, piers, and abutments for water stains. These may indicate leaky pipes, filled gutters, or scupper discharge pipes that are too short. (Stained abutments and piers could also mean leaky joints, however.)

c. *Drain Outlets.* Check to see that deck drain outlets (scuppers) do not discharge water where it may be detrimental to other members of the structure, cause fill and bank erosion, or spill onto a roadway below.

d. *Damaged Pipes.* Look for pipes damaged by freezing, corrosion, or collision. These will show cracks, holes, or stains.

e. *Clogged Pipes.* Check pipes, if possible. Open the cleanout at bottom of pipes to see whether pipes are open all the way through.

f. *Sand or Soil Accumulations.* Check for layers of sand or soil on the bridge deck. Presence of either of these will retain moisture and brine, and will accelerate deck scaling. Soil or sand deposits are clear indications of poor deck drainage.

## Section 25. DOLPHINS AND FENDERS

### 5–25.1 General.

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.

a. *Dolphin Types.*

(1) *Timber Pile Cluster Dolphins.* This type of dolphin consists of a cluster of timber piles driven into the harbor bottom with the tops pulled together and wrapped tightly with wire rope (fig. 5–99). It is widely used.

(2) *Steel Tube Dolphins.* 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) *Caisson Dolphins.* Caisson dolphins are sandfilled, 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. *Fender Types.*

(1) *Timber Bents.* A series of timber piles with timber walers and braces attached to the pile tops are still used (fig. 5–100). Steel piles are sometimes used in lieu of timber.

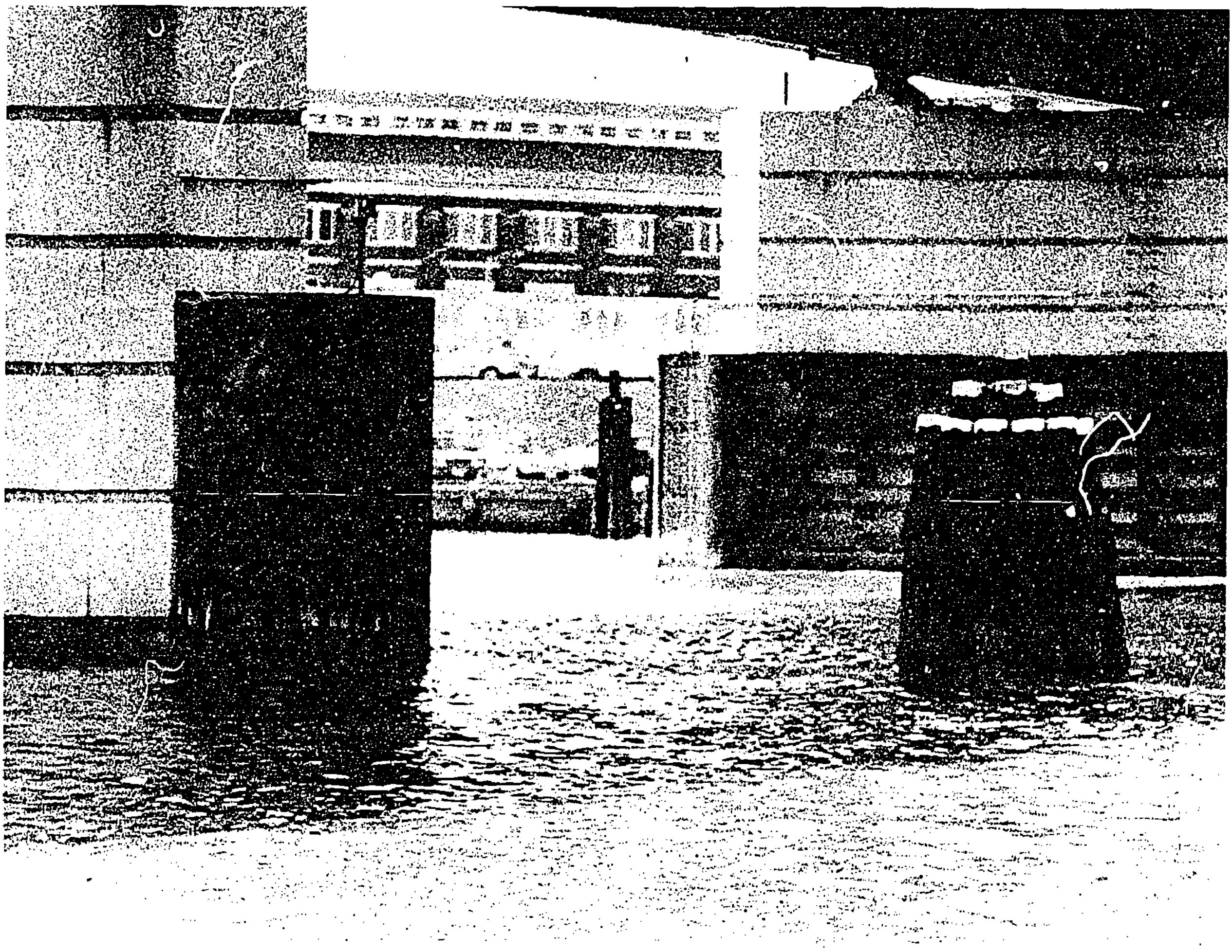


*Figure 5–99. Timber pile cluster dolphins and timber fender system on pier.*

(2) *Cofferdam Fenders.* 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 Piles.* 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 (figs. 5–99 and 5–101).

(6) *Floating Fenders.* Floating frameworks which partly or completely surround the pier are sometimes used as fenders. The main frames are usually made of steel or concrete with timber cushioning on the outside face.

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

### 5–25.2 Factors Causing Deterioration.

a. *Decay or Corrosion.* In steel or concrete, the deterioration is usually caused by the corrosive effects of the water (especially sea water). In timber, decay fungi and marine insects attack wood.

b. *Abrasion.* Timber fenders are particularly vulnerable to abrasion. Abrasion damages the wood and reduces the thickness of the treated layers protecting the wood. Metal and concrete also suffer from abrasion.

c. *Uplift.* Timber pile dolphins experience failure by uplift of some of the piles under lateral loads and ice loads.

d. *Weathering.* Timber well above the water line or water level is subject to weathering and deterioration.

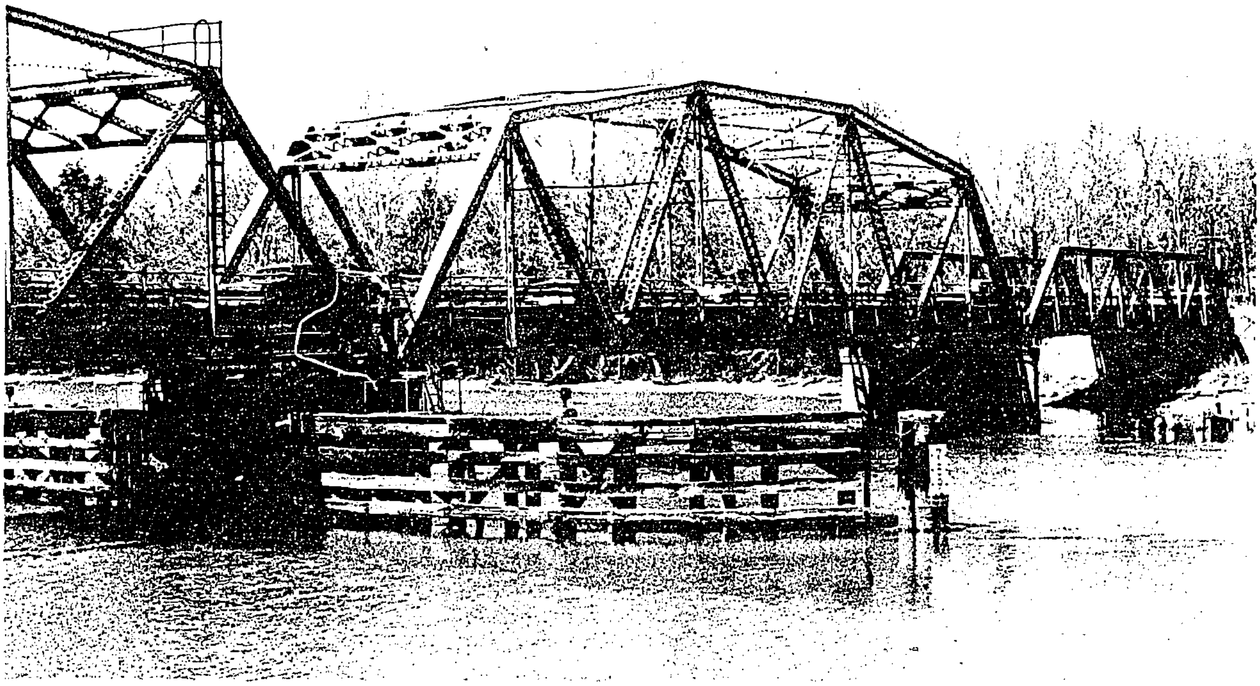


*Figure 5-100. Timber bent fenders.*

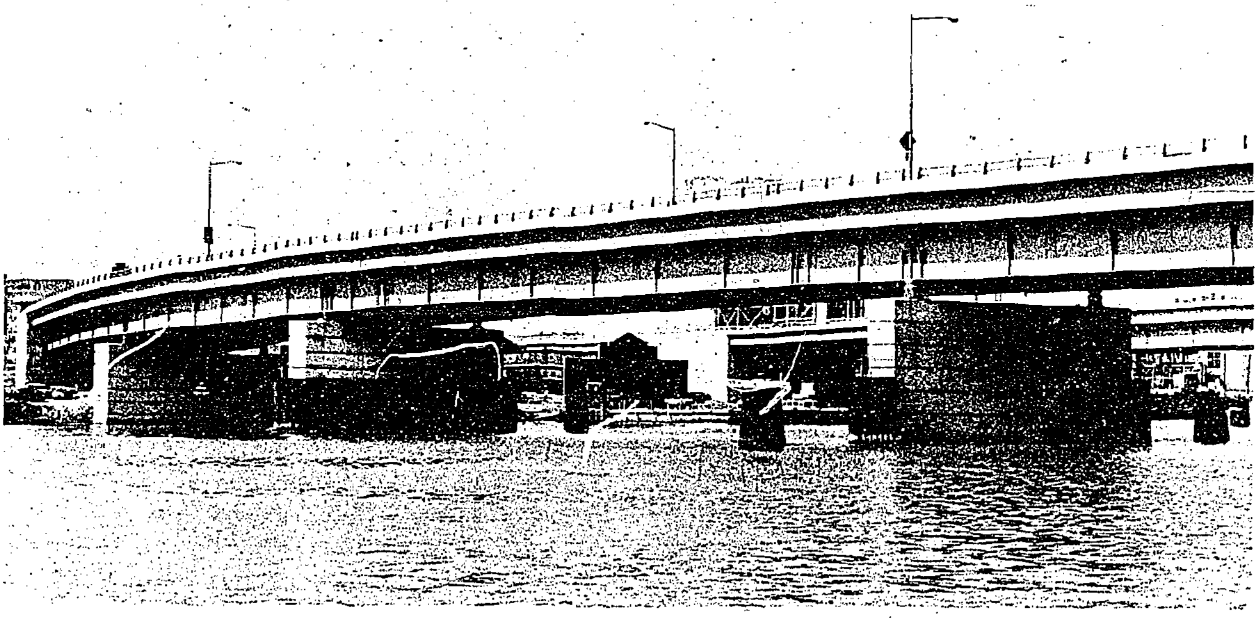


*Figure 5-101. Dolphins and timber fenders around piers of river bridge.*

5–25.3 What To Look For During Inspection.

a. *Steel.* Observe the "splash zone" carefully for severe rusting and pitting. The splash zone is the area from high tide to 2 feet above high tide. Where there are no tides, it is the area from the mean water level to 2 feet above it. Rusting is much more severe here than at mid-tide elevations.

b. *Concrete.* Look for spalling and cracking of concrete, and rusting of reinforcing steel. Be alert for hour-glass shaping of piles at the water line.

c. *Timber.* Observe the upper portions lying between the high water and mud line for marine insects and decay (fig. 5–102). Check the fender pieces exposed to collision forces for signs of wear.

d. *Structure Damage.* Check all dolphins or fenders for cracks, buckled or broken members, and any other signs of structural failures or damage from marine traffic.

(1) Piling and walers require particular attention since these are areas most likely to be damaged by impact.

(2) Note any loose or broken cables which would tend to destroy the effectiveness of the cluster. Note whether they should be re-wrapped.

(3) Note missing walers, blocks, and bolts.

e. *Protective Treatment.* Note any protective treatment that needs patching or replacing. This includes breaks in the surface of treated timbers, cracks in protective concrete layers, rust holes or tears in metal shields, and bare areas where epoxy or coal tar preservatives have been applied externally.

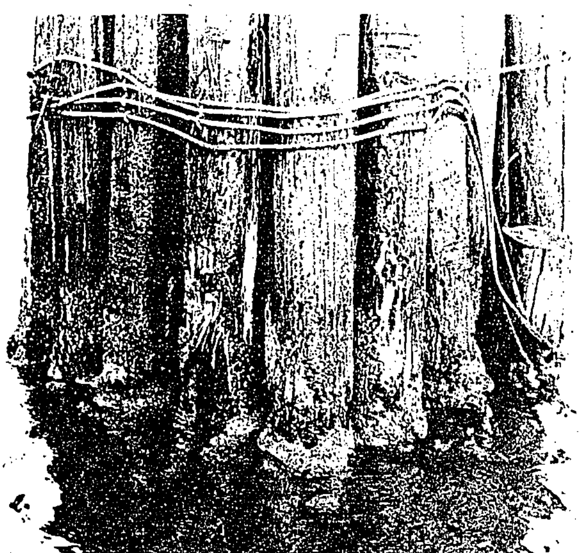


*Figure 5–102. Limnoria attack of a timber dophin.*

f. *Catwalks.* Note the condition of the catwalks for fender systems.

## Section 26. WATERWAYS

5–26.1 General.

Waterways should be inspected in order to determine whether any condition exists that could cause damage to the bridge or to the area surrounding the bridge. In addition to inspecting the channel's present condition, a record should be made of any significant changes that have taken place in the channel, attributable either to natural or artificial causes. When significant changes have occurred an investigation must be made into the probable or potential effects on the bridge structure. Events which tend to produce local scour, channel degradation, or bank erosion are of primary importance.

a. *Scour.* Scour is defined as the removal and transportation of material from the bed and banks of rivers and streams as a result of the erosive action of running water. Some general scouring takes place in all stream beds, particularly at flood stage. The characteristics of the channel influence the amount and nature of scour. Accelerated local scouring occurs where there is an interference with the stream flow, e.g., approach embankments extended into the river or piers and abutments constructed on the river bottom. The amount of scour in such cases depends on the degree to which stream flow is disturbed by the bridge and on the susceptibility of the river bottom to scour action. Scour depth may range from zero in hard rock to thirty feet or more in very unstable river bottoms. In determining the depth of local scour, it is necessary to differentiate between true scour and apparent scour. As the water level subsides after flooding, the scour holes that are produced tend to refill with sediment. Elevations taken of the stream bed at this time will not usually reveal true scour depth. However, since material borne and deposited by water will usually be somewhat different in character from the material in the substrata, it is often possible to determine the scour depth on this basis. If, for example, a strata of loose sand is found overlying a hard till substratum, it is reasonable to assume that the scour extends down to the depth of the till. This can often be confirmed by sounding or probing, provided the scour depth is limited to a few feet. Where coarse deposits or clays are encountered, sounding will probably be unsuccessful.

b. *Stream Bed Degradation.* Stream bed degradation is usually due to artificial or natural alteration in the width, alignment, or profile of the channel. These alterations which may take place at the bridge site or some distance upstream or downstream, upset the equilibrium, or regime, of the channel. A channel is said to be in regime if the rate of flow is such that it neither picks up material from the bed nor deposits it. In the course of years the channel will gradually readjust itself to the changed condition and will tend to return to a regime condition. Stream bed degradation and scour seriously endanger bridges whose foundations are located in erodible river bed deposits and where the foundation does not extend to a depth below that of anticipated scour. Removal of material adjacent to the foundation may produce lateral slope instability causing damage to the bridge. Either concrete slope protection (fig. 5–103) or riprap (fig. 5–104) is often provided to prevent bank erosion or to streamline the flow at obstructions. It is particularly important where flow velocities are higher or where considerable turbulence is likely. It may also be necessary where there is a change in direction of the waterway. Slope cones around abutments are very susceptible to erosion and are usually protected.

c. *Waterway Adequacy.* Scour and stream bed

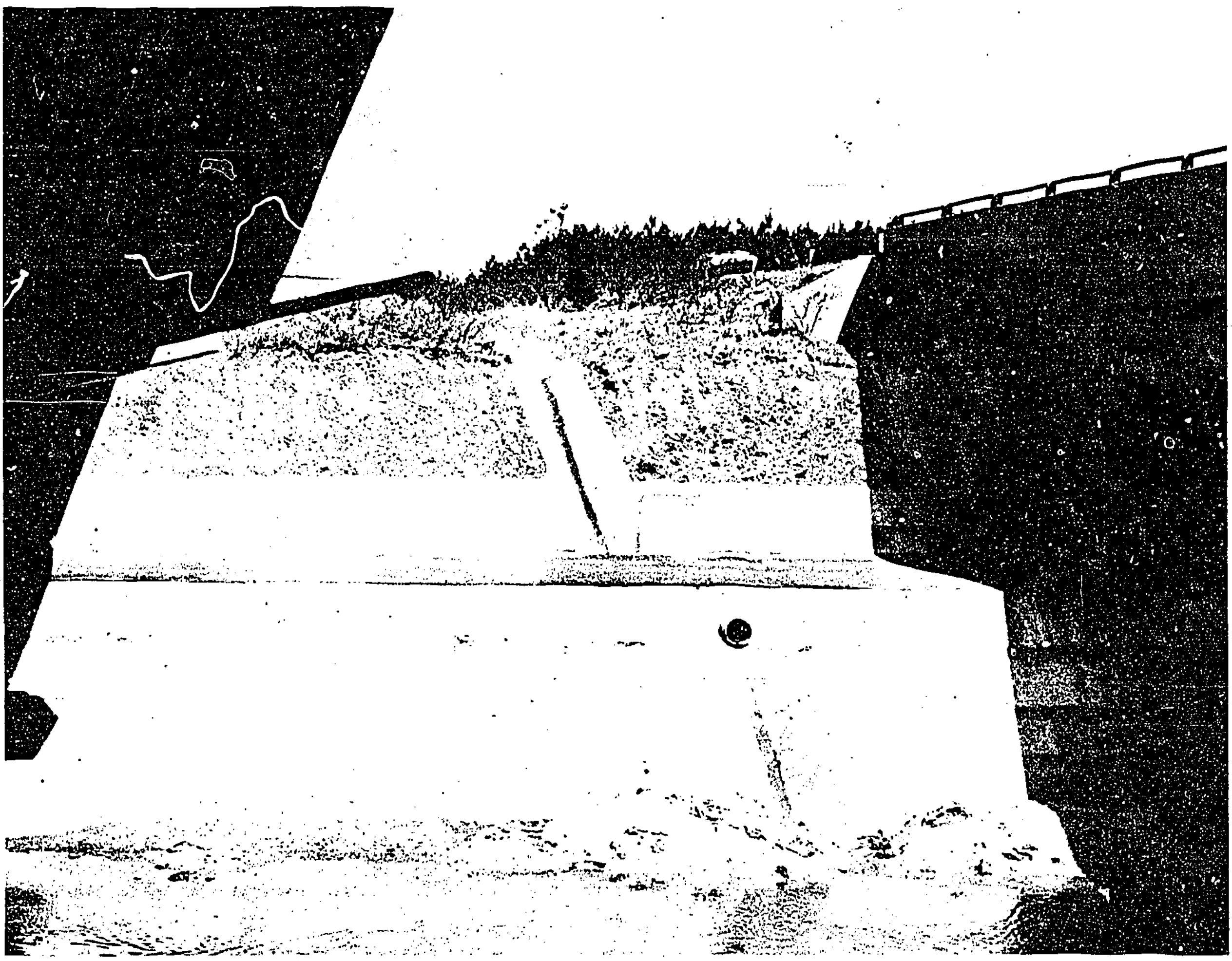


*Figure 5–103. Concrete lined channel.*

degradation are actually the result of inadequate waterway areas. The geometry of the channel, the amount of debris carried during high water periods, and the adequacy of freeboard should be considered in determining waterway adequacy. Where large quantities of debris and ice are expected, sufficient freeboard is of the greatest importance.

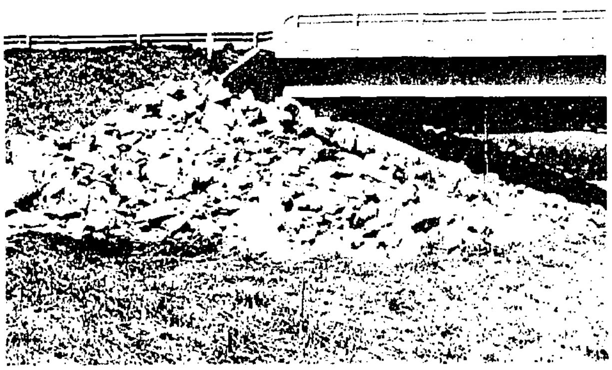


*Figure 5–104. Slope cone protected by stone riprap.*

### 5–26.2 What to Look for During Inspection.

a. *Maximum Water Level.* Ideally, waterways should be inspected during and immediately following periods of flood, since the effects of high water will be most apparent at these times. Since this is not always possible, a knowledge of the heights of past major floods from stream gauging records, or from other sources, together with observations made during or immediately following high water, are helpful in determining the adequacy of the waterway openings. Other sources are:

(1) High water marks or ice scars left on trees

(2) Water marks on painted structures

*Figure 5–105. Drift and debris deposited in channel following flood.*

(3) Debris wedged beneath the deck of the bridge or on the bridge seats

(4) Information from established local residents.

b. *Insufficient Freeboard.* This is a prime characteristic of inadequate waterways. In addition to the signs mentioned previously, lateral displacement of old superstructures is a prime indication of insufficient freeboard.

c. *Debris.* Debris compounds the problems of a scanty freeboard. Check for debris deposits along the banks upstream and around the bridge (fig. 5–105).

d. *Obstruction.* Debris or vegetation in the waterways, both upstream and downstream, may reduce the width of the waterway, contribute to scour, and even become a fire hazard. Sand and gravel bars formed in the channel may increase stream velocity and lead to scour near piers and abutments.

e. *Scour.*

(1) *Channel Profile.* In stream beds susceptible to scour and degradation, a channel profile should be taken periodically. Generally 100-foot intervals, extending to a few hundred feet upstream and downstream, should be sufficient. This information, when compared with past records, will often reveal such problems as scour tendencies, shifts in the channel, and degradation.

(2) *Soundings.* Soundings for scour should be taken in a radial pattern around the large river piers.

(3) *Shore and Bank Protection.*

(a) Examine the condition and adequacy of existing bank and shore protection.

(b) Check for bank or levee erosion caused by improper location or skew of the bridge piers or abutments.

(c) Note whether channel changes are impairing or decreasing the effectiveness of the present protection.

(d) Determine whether it is advisable to add more channel protection or to revise the existing protection.

f. *High Backwater.* Be particularly alert for locations where high fills and inadequate or debris-jammed culverts may create a very high backwater. The fill acts as a dam, and with the possibility of a washout during rainfall, a disastrous failure could result (fig. 5–121).

g. Observe the effect of wave action on the bridge and its approaches.

h. Observe the areas surrounding the bridge and its approaches for any existing or potential problems, such as ice jams.

i. Observe the condition and functioning of existing spur dikes.

### 5–26.3 Illustrations of Waterway Problems.

The following illustrations show some of the more common waterway problems.

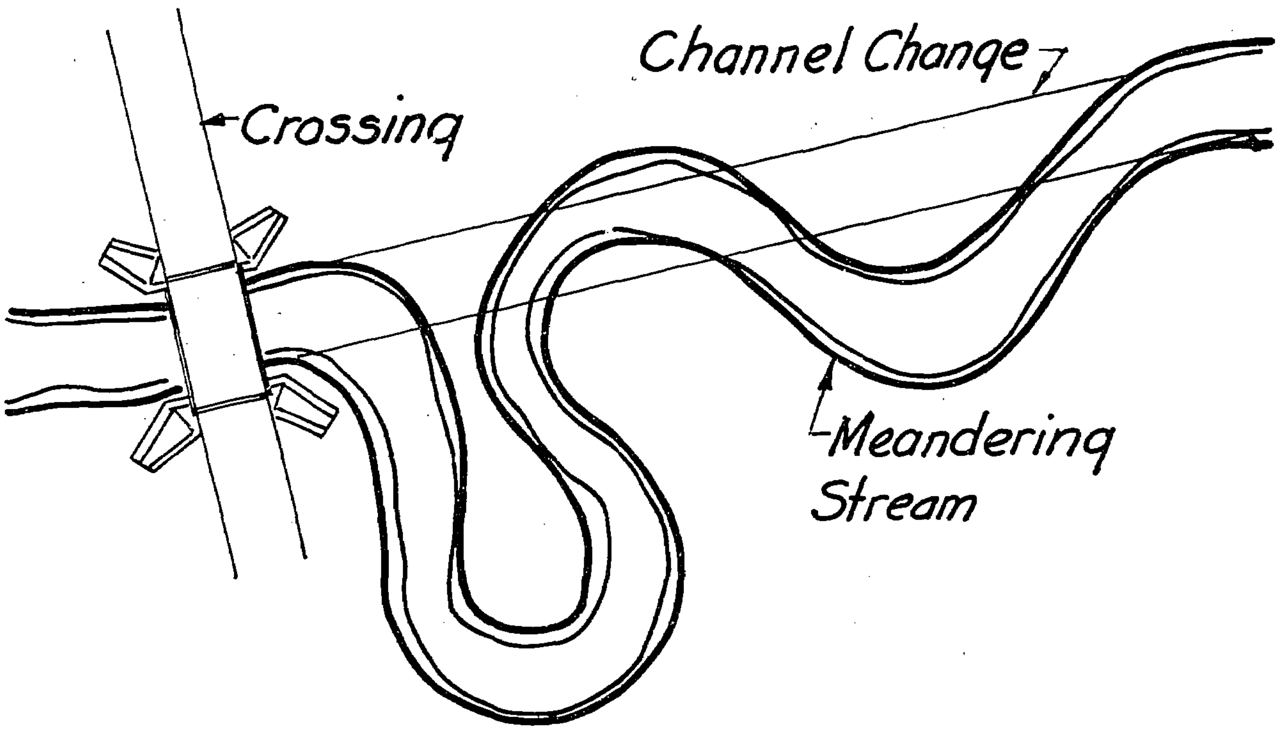



*Figure 5–106. Channel change. The channel change steepens the channel profile and increases flow velocity. The entire section may degrade.*

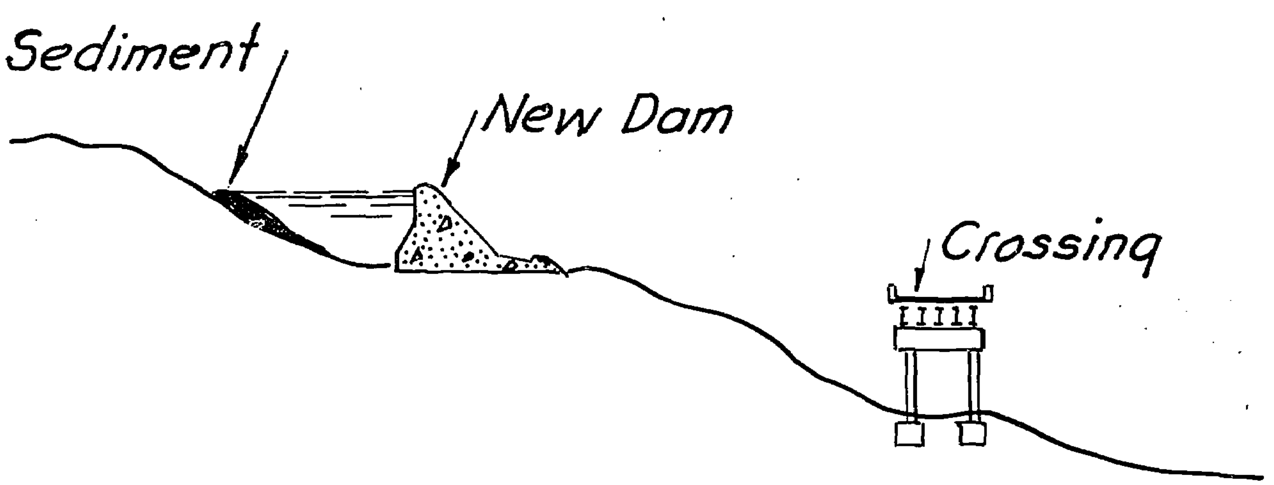



*Figure 5–107. Sediment deposits. Sediment previously carried downstream is deposited in the reservoir, which acts as a settling basin. The increased scour capability of the downstream flow may degrade the lower channel.*

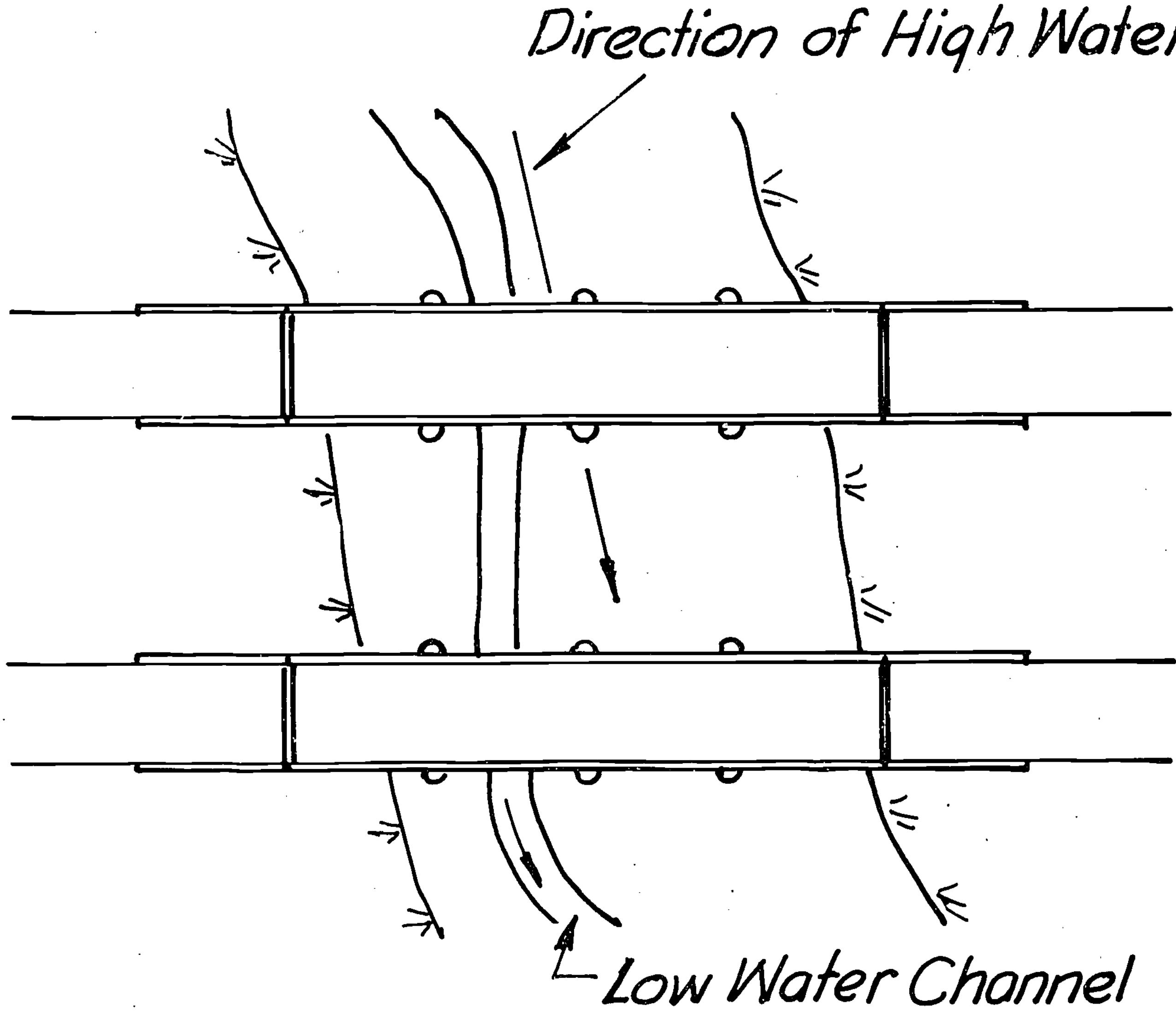



*Figure 5–108. Pier scour. Scour around piers is influenced greatly by the shape of pier and skew to flood flow. Note direction of flood flow is different from that of normal channel flow.*

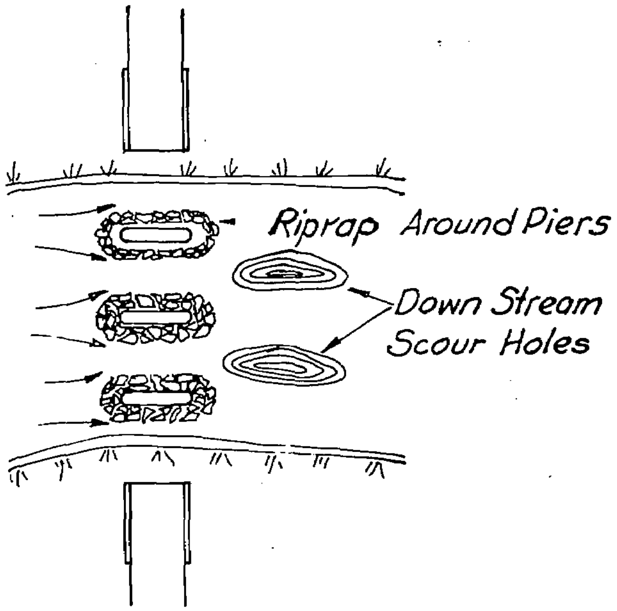



*Figure 5–109. Loose riprap. Loose rock riprap piled around piers to prevent local scour at the pier may cause deep scour holes to form downstream.*

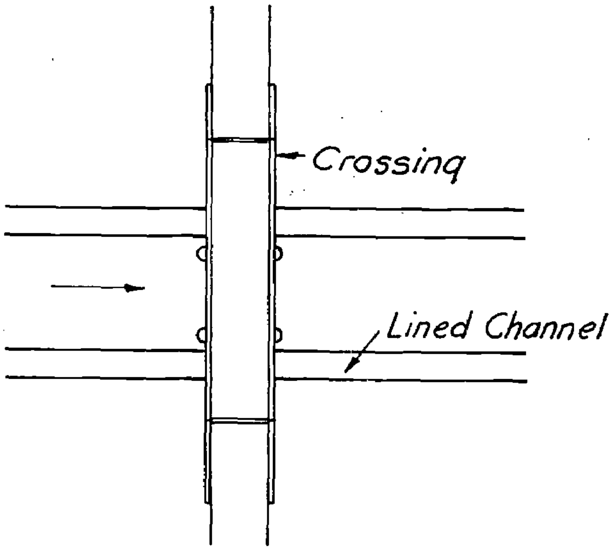



*Figure 5–110. Lined banks tend to reduce scour, but such a constriction might increase general scour in the bridge opening, especially at an adjacent or end pier.*

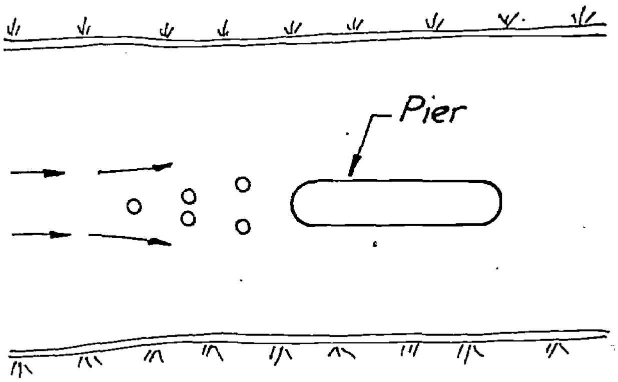



*Figure 5–111. Scour reduction. Scour at the pier may be reduced significantly by placing piles upstream in a wedge shaped pattern as shown.*

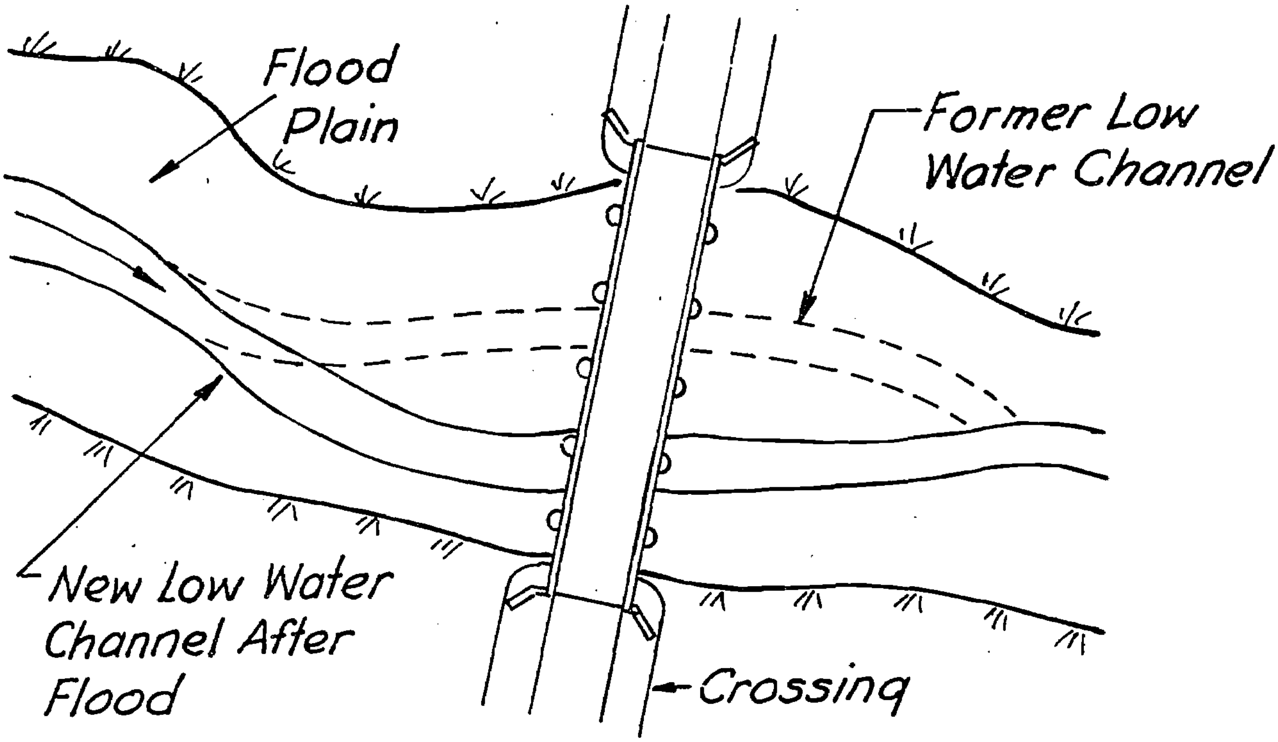



*Figure 5–112. Channel change. New low water channel is formed during flood at the river bend.*

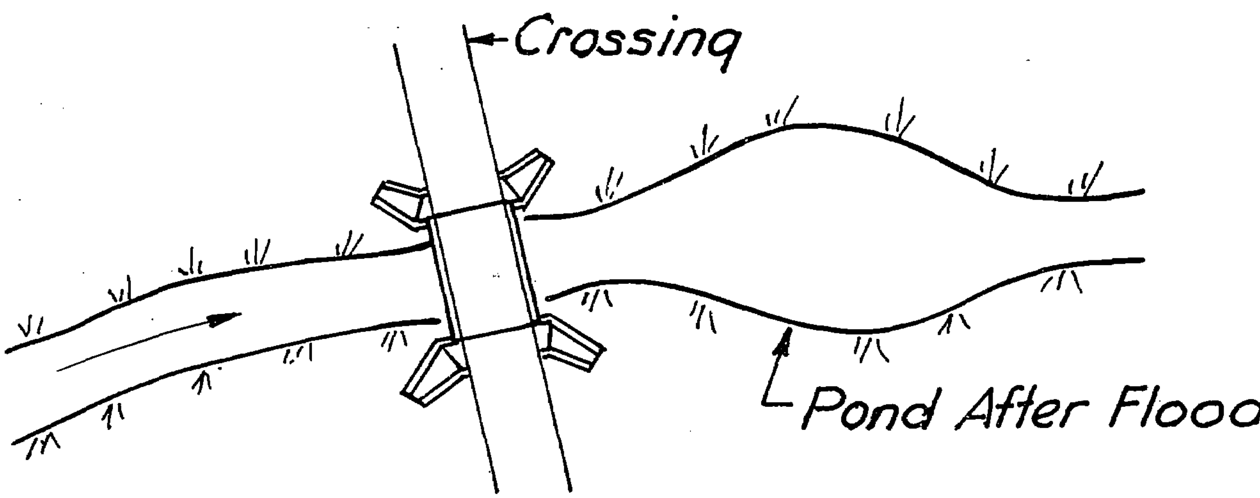



*Figure 5–113. Horizontal or vertical channel constrictions. A firm or riprapped bottom or a horizontal constriction can cause a deep scour hole downstream with severe bank erosion resulting in downstream ponding as shown in the sketch.*

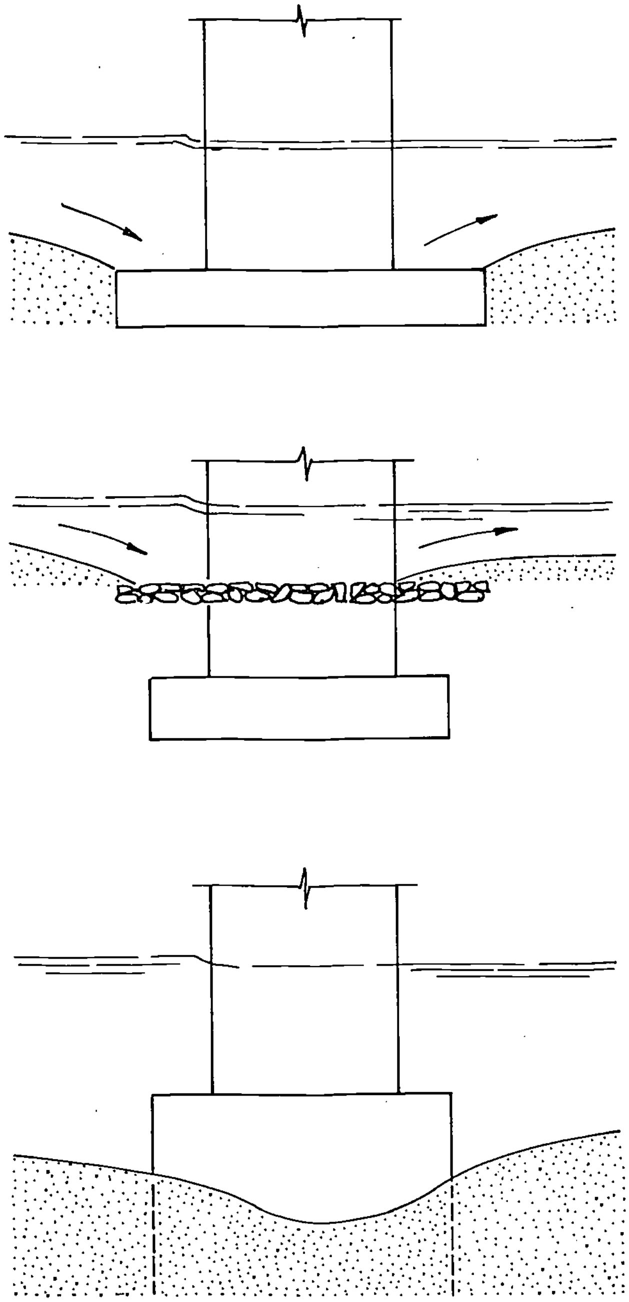


Figure 5–114. Scour reduction. Wide footings or rock aprons beneath the bed level tend to reduce scour by deflecting downward currents. A projecting foundation on the other hand will tend to increase depth of scour.

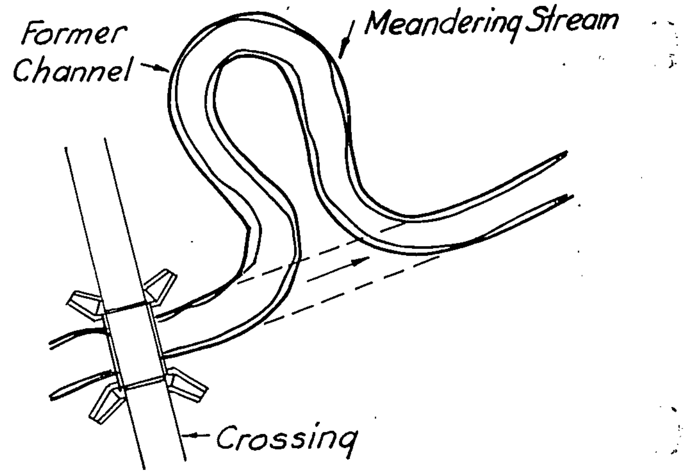



Figure 5–115. New channel. New channel cuts off oxbow and changes the river profile. The upstream reach may degrade.

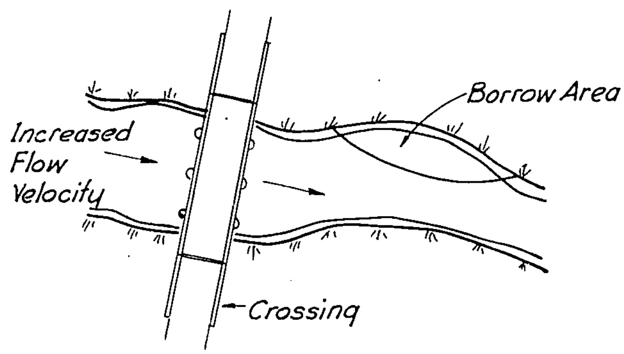



Figure 5–116. Gravel removal leading to upstream degradation. Removing large quantities of gravel from river bottom causes degradation upstream.

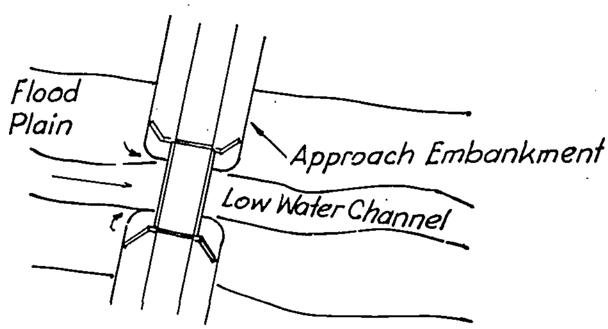



Figure 5–117. Scouring during flood. During flood the waterway constriction may produce general scouring in the vicinity of the bridge.

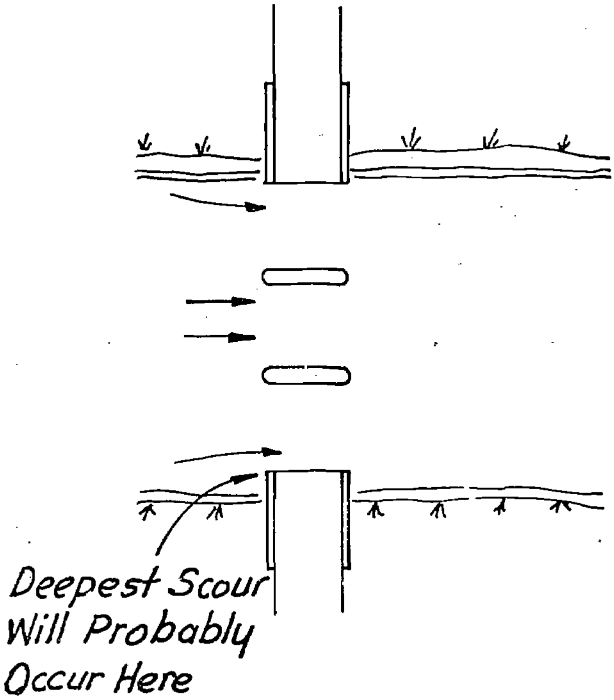



*Figure 5–118. Scour due to protruding abutments. Protruding abutments may produce local scour. Deepest scour usually takes place at the upstream corner. The severity of scour increases with increased constriction.*

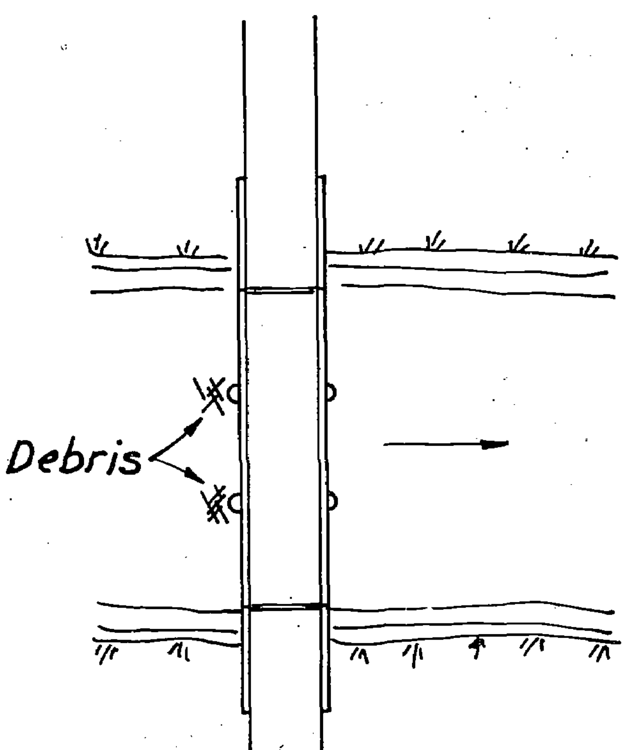



*Figure 5–119. Scour due to debris. Collection of debris around piers, in effect, enlarges the size of the pier and causes increased area and depth of scour.*

### Section 27. BOX CULVERTS

**5–27.1 General.**

Box culverts range in size from small single cell units to multi-cell units as large as 20′ x 20′. While natural rock, when present, may be used as a floor, the box culvert (fig. 5–120) is usually a closed, rectangular frame. Usually, transverse joints are provided every 20′ to 30′. Occasionally, old culverts consist simply of 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 rubble masonry, rather than concrete.

**5–27.2 Types of Culvert Distress.**

A culvert is generally used where its construction would permit a fill to substitute for a bridge without any loss of vital waterway area. This combination of high earth loads, long pipe-like structures, and running water tends to produce the following types of distress:

a. The basic causes and actions of foundation movements are discussed in Section 5–7. Here, they need only be listed.

(1) Settlement of the box. This may be either a smooth sag, or it may be differential settlement at the expansion joints.

(2) Tipping of wing walls.

(3) Lateral movements of sections of the box.

b. High embankments may impose very heavy loads on the top and bottom slabs. These earth pressures can cause either shear or flexural failures in the top slabs.

c. Construction defects can lead to structural distress.

d. Undermining is a form of scour attack on the upstream and downstream ends of box culverts. When sheeting, or a concrete cut-off wall, is either not provided or is not deep enough, the stream may wash away the soil under the ends of the floor slab, the apron, or the wing wall footings, leading to settlements and culvert cracking.

e. Plugging may result from debris collecting over the mouth of the culvert. This can cause flooding (fig. 5–121) and flotation and displacement of part, or all, of the box.

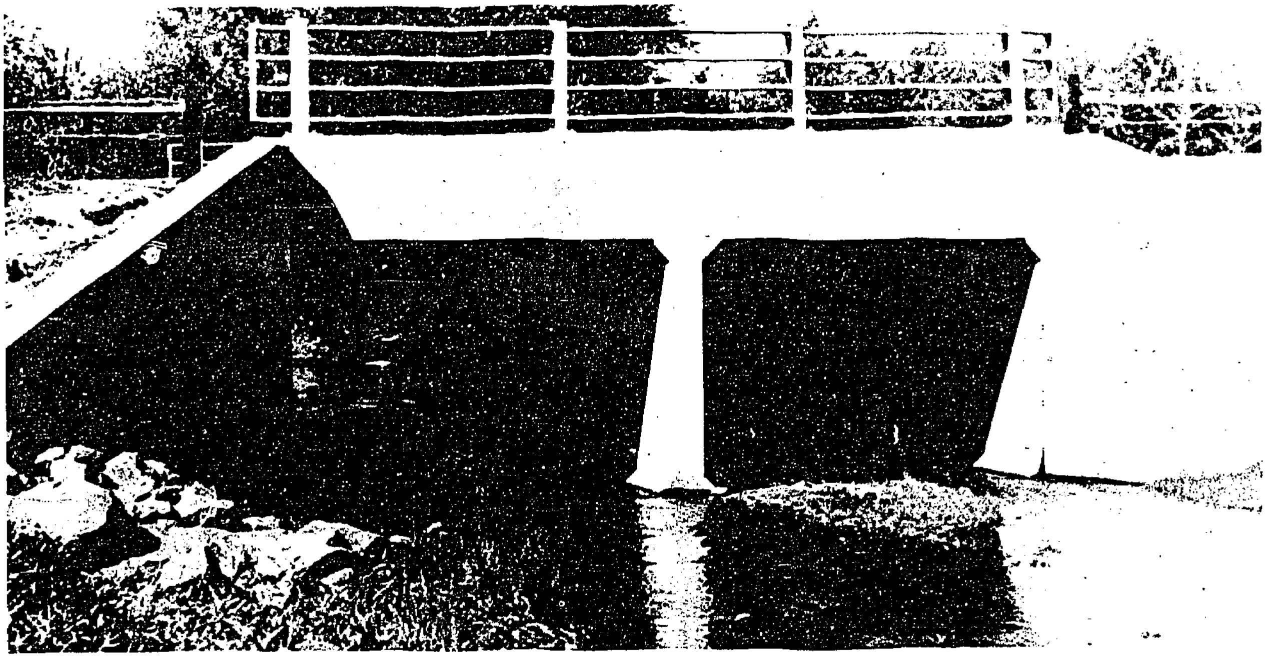


*Figure 5–120. Two-barrel box culvert.*

f. Water leaving the box at high velocities may cause downstream scour at the stream bed.

### 5–27.3 What to Look for During Inspection.

a. Check for sag of the culvert floor. In times of light flow, this may be noted by location of sediment. Where there are several feet of water in the box, a profile of the crown may be taken.

b. Check for sag in the profile of the roadway overhead.

c. Check for vertical differential settlement at the expansion joints.

d. Check for transverse and longitudinal differential settlements at the expansion joints.

e. Check for widely opened expansion joints. Water may be seeping through joints from soil outside.

f. Check for canted wingwalls. This condition may be due to settlement, slides, or scour.

g. Check for slide failures in the fill around the box. Such slides are likely to affect the box as well.

h. Check for cracks and spalls in the top slab. Longitudinal cracks indicate either shear or flexure problems; transverse cracks indicate differential settlement. Cracks in the sides may be from settlement or from extremely high earth pressures. Note the size, length, and location of the crack. Look for exposed or rusty rebars.

i. Where there is no bottom slab, look for undermining of side footings.

j. Check for undermining at the ends of the box and under the wings.

k. Examine the inside of the box for large cracks and debris. This may indicate the need for a debris rack. Check the inlet end of the culvert for debris. Note whether vegetation is obstructing the ends of the culvert.

l. If the culvert floor is visible, check it for abrasion and wear.

m. Note any other signs of deterioration of the concrete box, especially those which suggest design error or construction omissions.

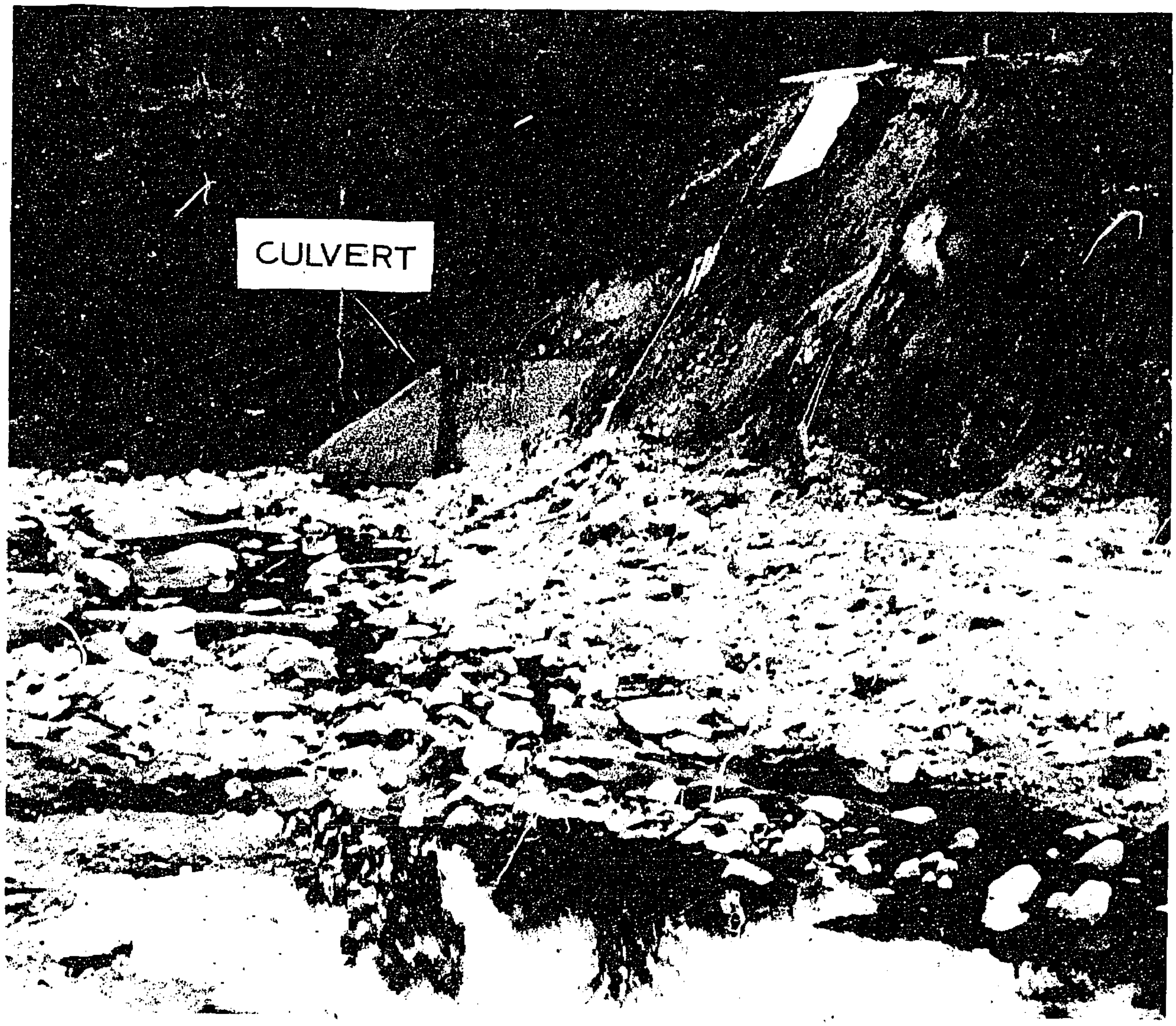



*Figure 5–121. Roadway washed out by flood. Note that culvert is still intact.*

### Section 28. PAINT

#### 5–28.1 General.

Since painting is the primary means for protecting structural steel against rust and corrosion, it is imperative that the condition of the paint applied to the structural steel elements of the bridge be thoroughly inspected and fully reported upon. Continual exposure to the effects of weathering and chemical action requires that paint be continually maintained. Spot failures can develop rapidly into large areas of corrosion which, if permitted to continue over a period of time, can cause extensive and, possibly, irreparable damage to the bridge. The life of many bridges has been significantly reduced because of neglected painting. The amount of paint maintenance required is influenced by the environment. In damp coastal regions, or in urban industrial areas, a program of annual spot painting may be necessary, and complete repainting of the bridge structure may be required as often as every four or five years. In dry climates, repainting may not take place for as long as 10 years and, in some cases, the interval between painting may approach 15 years. Other factors affecting the life of the paint are type, quality of its application, structural details, and the amount of exposed areas.

## 5–28.2 What to Look for During Inspection.

a. Examine all paint carefully for cracking or chipping, scaling, rust pimples, and chalking. Look for evidence of "alligatoring." If the paint film has disintegrated, note whether the prime coat or the surface of the metal is exposed. Note the extent and severity of the paint deterioration. If extensive "spot" painting will be required, probably the entire structure should be repainted; otherwise, "spot" painting will most likely be sufficient.

b. Look for paint failure on upper chord horizontal surfaces, or those surfaces which are most exposed to sunlight or moisture. Give particular attention to areas around rivets and bolts, the ends of beams, the seams of built-up members, the unwelded ends of stiffeners, and any other areas that are difficult to paint or that may retain moisture.

# *Section 29. SIGNING*

## 5–29.1 General.

This section is concerned with the presence and effectiveness of bridge signing. Both the signs and the sign support structures should be inspected.

## 5–29.2 What to Look for During Inspection.

a. *Type of Signs.* When inspecting a bridge for signing, note not only the signs that are posted, but whether additional signs are needed because of changed bridge or roadway conditions. The types of warning and regulatory signs that are normally required are:

(1) *Weight Limit.* This is the most important inspection item particularly for the older bridges (fig. 5–122). If the bridge structure was designed and constructed prior to 1940, capacity of the bridge may be a problem.

(2) *Vertical Clearance.* While most newer bridges have adequate vertical clearances, older bridges are often substandard in this respect. Where no limiting vertical clearances are posted for old through-truss bridges, railroad underpasses, or old grade separations, measure the clearances to determine whether they meet the established legal minimum standard. Any clearance that is less than 1 foot higher than the legal height and load limit should be posted with a "Low Clearance" sign (fig. 5–123 and 5–124).

(3) *Lateral Clearance.* Many new bridges are narrower than they should be. "Narrow Bridge" signs and striped paddleboards (fig. 5–124), should be used when the bridge width is less than that of the approach roadway. If the superstructure or parapet end extends above the curb, it should be striped and a reflectorized hazard marker should be attached.

(4) *Narrow Underpasses.* Where the roadway narrows at an underpass, or where there is a pier in the middle of the roadway, striped hazard markings should be placed on the abutment walls and on pier edges. Reflective hazard markers should also be placed on the piers and abutments, and the approaching pavement should be appropriately marked to warn the approaching traffic of the hazard.

(5) *Speed and Traffic Markers.* These types of signs should be checked to ascertain whether they are appropriate. Speed restrictions should be carefully noted to determine whether such restrictions are consistent with bridge and traffic conditions. Additional traffic markers may be required to facilitate the safe and continuous flow of traffic.

(6) *Movable Bridges.* Signs warning of draw spans (fig. 5–123) and submarine cables, should be posted. Interconnected traffic signals and drawbridge gates should also be provided. (See Section 5–32 dealing with movable bridges.)

b. *Locations of Signs.* The warning signs should be located sufficiently in advance of the structure to permit the driver and his vehicle to react. The weight limit sign, being regulatory, should be located just ahead of the bridge. Lateral clearance of the sign should be determined by the requirements of the highway type. On freeways, side-mounted signs should be:

(1) Positioned 30 feet from the edge of the travel way,

(2) Located behind a barrier, guardrail, or

(3) Affixed to a breakaway installation. On other highways, signs should preferably be located behind a barrier, guardrail or be affixed to a breakaway standard. Any sign support of sufficient mass to be a hazard, which does not meet the preceding criteria, should be noted and reported.

c. *Condition.* It is important that all caution signs be in good condition. Evaluation of the condition and adequacy of the signing will depend upon the conditions prevailing in a given area. It is suggested that the Manual on Uniform Traffic Control Devices (MUTCD) be consulted for specific information with regard to signing. Signs should be checked for:


*Figure 5–122. Safety poster illustrating the danger of ignoring load limit signs.*

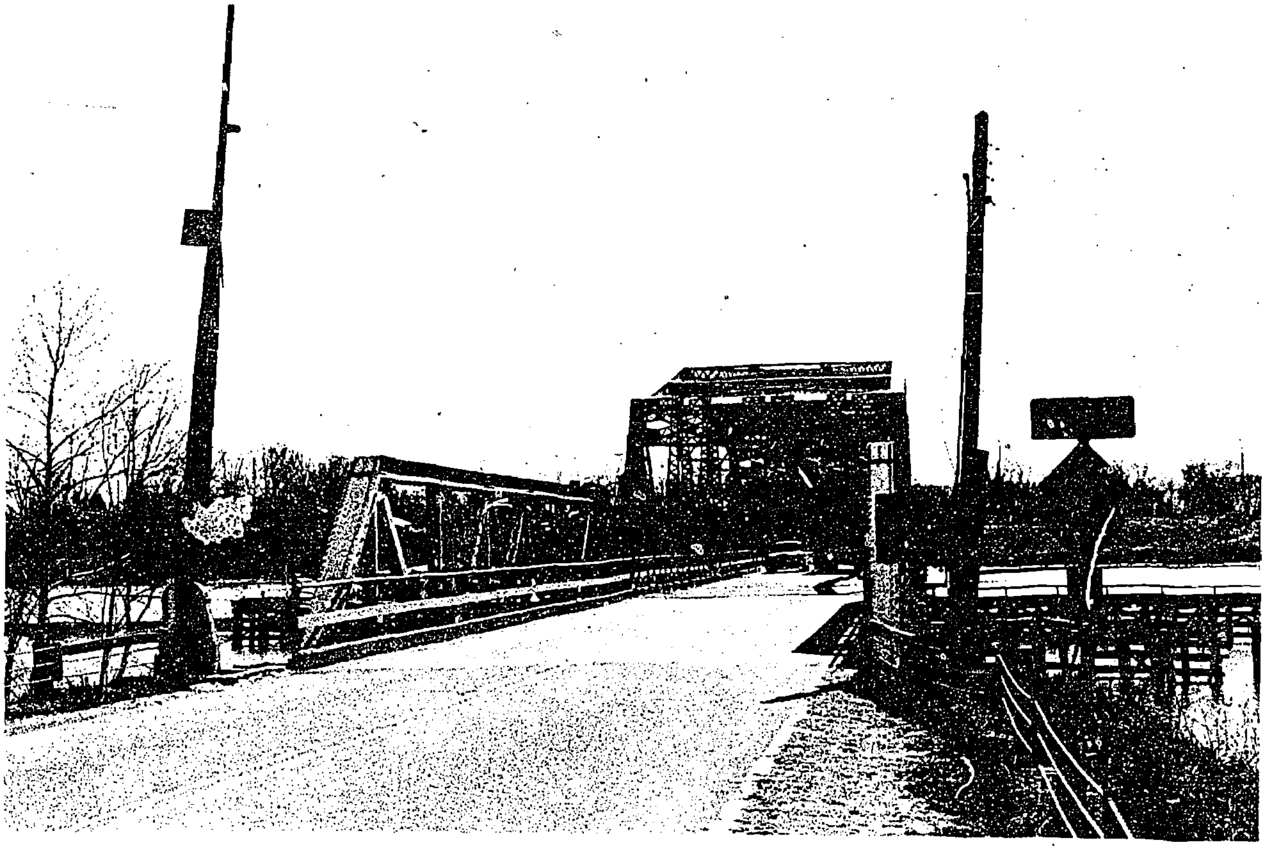


*Figure 5–123. Warning signs on approaches to swing bridge.*

(1) *Reflectorization.* Adequate reflectorization and/or painting are required for night visibility.

(2) *Legibility.* Note whether the legend is difficult to read. This may be because of dirt encrustment, dulled paint, inadequate lettering, or inadequate sign size. Refer to the Manual on Uniform Traffic Control Devices for Streets and Highways for guidelines as to criteria to be followed in evaluating sign legibility.

(3) *Vandalism.* Bullet holes, paint smears, campaign stickers, etc. should be noted.

(4) *Minimum Sizes.* In general, most warning signs are diamond-shaped and measure at least 30″ x 30″. "Low Clearance" signs are 36″ x 36″. The "Weight Limit" signs are rectangular with minimum dimensions of 18″ x 24″.

(5) *Vegetation.* On minor roads, heavy vegetation growth may obscure signs. Note the type and location of such vegetation so that it may be trimmed or removed entirely. If relocation of the sign(s) is necessary, include such remarks in the inspection report.

(6) *Sign Support Damage.* Note whether sign supports are bent, twisted, or otherwise damaged.

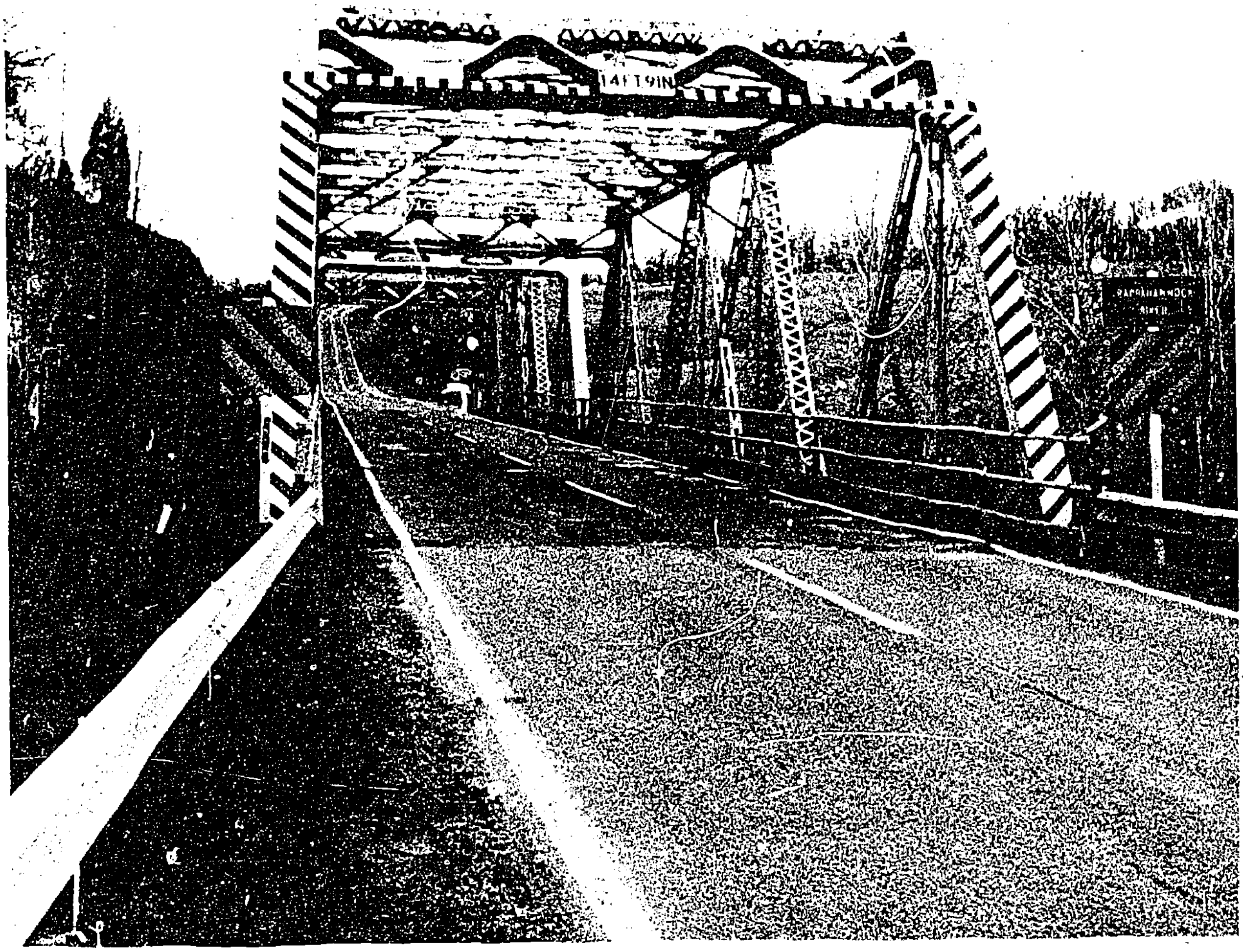



*Figure 5–124. Approach to narrow bridge. Note paddle boards and striping of endposts and portal chord.*

## Section 30. UTILITIES

### 5–30.1 General.

a. It is common for commercial and industrial utilities to use highway rights-of-way and/or adjacent areas in order to provide goods and services to the public. To bridge engineers, this means that some utility operations will be found on a number of bridge structures (fig. 5–125). These operations may be one or more of the following: gas, electricity, water, telephone, sewage, and liquid fuels.

b. Utility companies perform most of their 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 fasciae. On older bridges, water pipes and sewer pipes may be installed along the sides of the bridge or may be suspended under the bridge.

### 5–30.2 What to Look for During Inspection.

a. Check pipe, ducts, etc., for leaks, breaks, cracks, and deteriorating coverings.

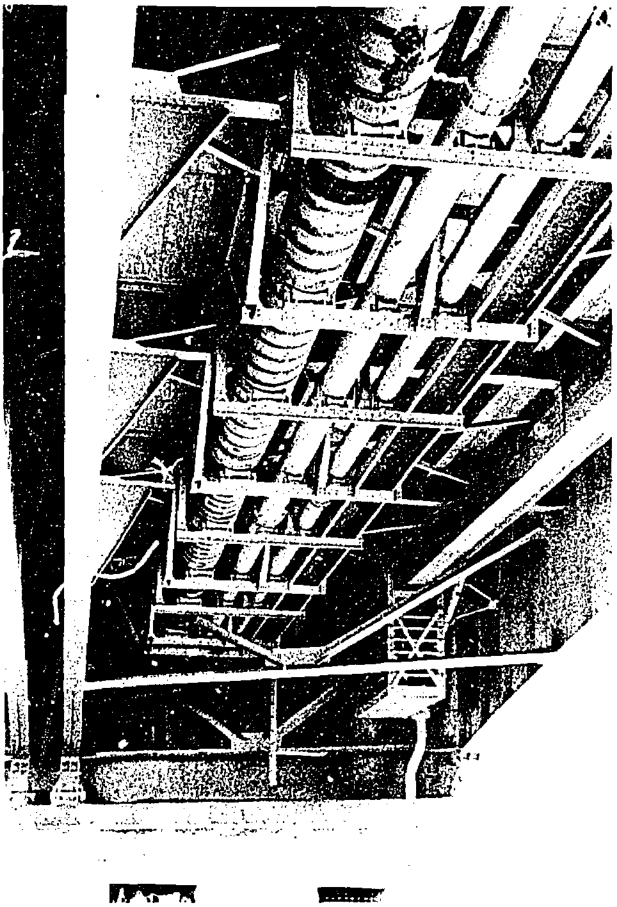


*Figure 5-125. Utility installations on bridge.*

b. Check the supports for signs of corrosion, damage, loose connections, and general lack of rigidity. If utility mounts rattle during passage of traffic, especially on steel bridges, note need for padding.

c. Check the annular space between pipe and sleeve, or between the pipe and the blocked up area for leaks where utilities pass through abutments.

d. Check for leaky water or sewer pipes located above the decks or on top of beams. Leakage from these pipes can cause serious corrosion of the deck or beams.

e. Inspect the area under water or sewer pipes for damage.

f. Determine whether mutually hazardous transmittants, such as volatile fuels and electricity, are sufficiently isolated from each other. If such utilities are side-by-side or in the same bay, report this condition for either auxiliary encasement or future relocation.

g. Check utilities that are located beneath the bridge for adequate roadway clearances.

h. Determine whether any utility obstructs the waterway area or are positioned so that they may hinder drift removal during periods of high water.

i. Check the encasement of pipes carrying fluids under pressure for damage, and check vents or drains for leaks.

j. Check for the presence of shut-off valves on pipelines carrying hazardous pressurized fluids, unless the fluid supply is controlled by automatic devices.

k. Note whether any utility is located where there is a possibility that it may be struck and damaged by traffic or by ice and debris carried by high water.

l. Determine whether utilities are adequately supported and whether they present a hazard to any traffic which may use or pass under the bridge.

m. Check for wear or deteriorated shielding and insulation on power cables.

n. Check for any adverse effect utilities may have on the bridge, e.g., interference with bridge maintenance operations or an impairing of structural integrity.

o. Check to determine whether vibration or expansion movements are causing cracking in the support members.

p. Check supporting members of the bridge for paint damage.

q. Note any adverse aesthetic effect utilities may have on the bridge.

## Section 31. LIGHTING

### 5-31.1 General.

Lighting on bridges will consist of "whiteway" lighting, sign lights, traffic control lights, navigation lights (fig. 5-126), 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.

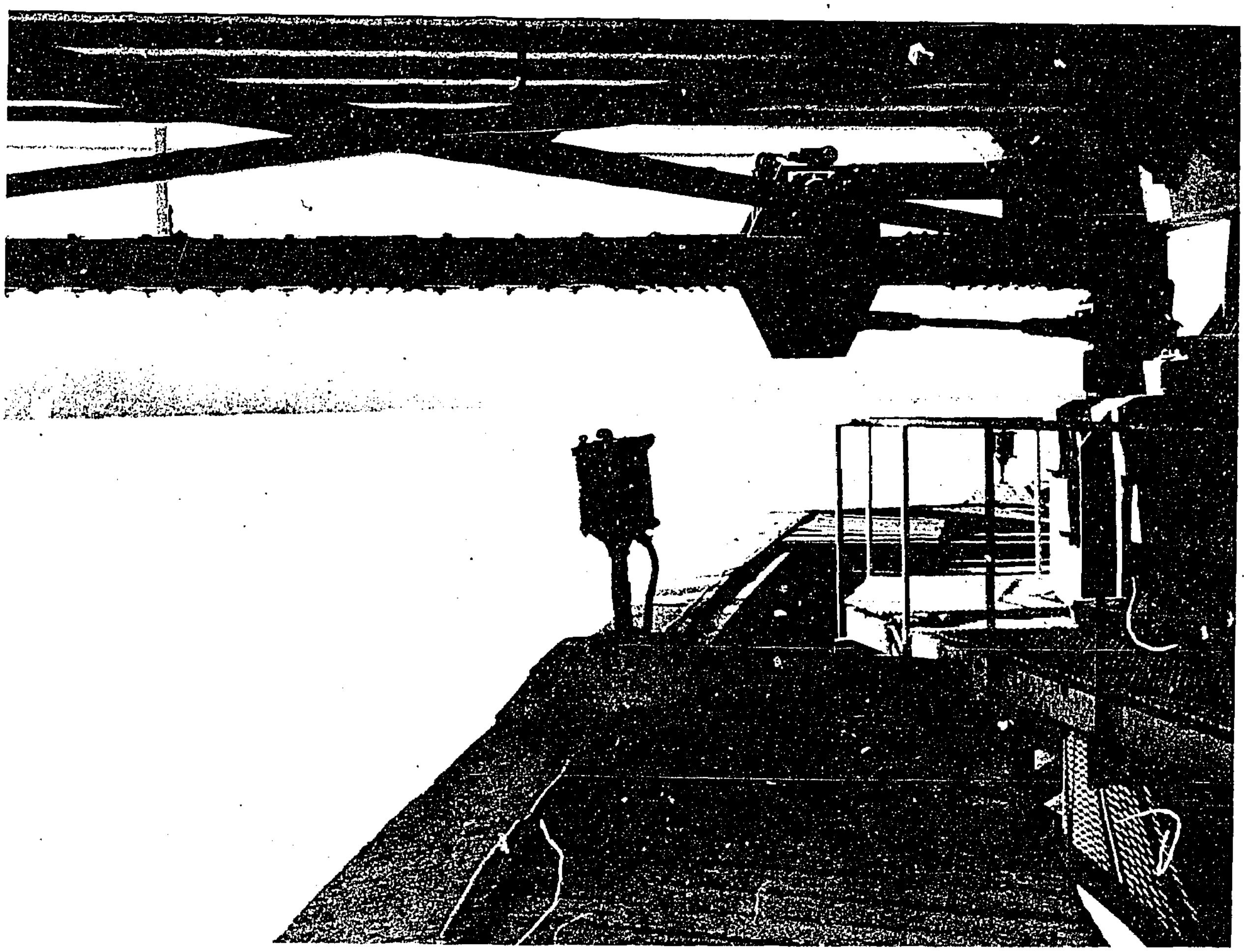


*Figure 5–126. Navigation light on pier.*

### 5–31.2 Highway Lighting.

Conventional highway lighting on bridges presents relatively few problems. The most common problems are discussed below.

a. *Collisions.* Most light standards on the more modern bridges are supported on parapets, or are located outside the rails. However, on some older urban bridges, light standards may be unprotected and, consequently, they are more vulnerable to damage or destruction from vehicles.

b. *Vandalism and Burnouts.* Generally, damaged lighting elements and dead bulbs are replaced routinely by maintenance forces. Nevertheless, such items should be noted and reported by bridge inspectors.

### 5–31.3 Navigation Lights.

Coast Guard Publication 208 lists the requirements for the type, number, and placement of navigation lights on bridges. It should be noted that Coast Guard District Commanders have the authority to waive requirements for navigation lights on bridges.

### 5–31.4 Aerial Obstruction Lights.

These lights are required on all bridges projecting far enough above ground to be a possible hazard to aircraft. If the tops of the bridges are not much higher than the surrounding buildings or trees, obstruction lights are probably unnecessary. The requirements for aerial obstruction lights may be waived at the discretion of the Federal Aviation Administration Regional Director.

### 5–31.5 What to Look for During Inspection.

a. *Whiteway Lighting.*

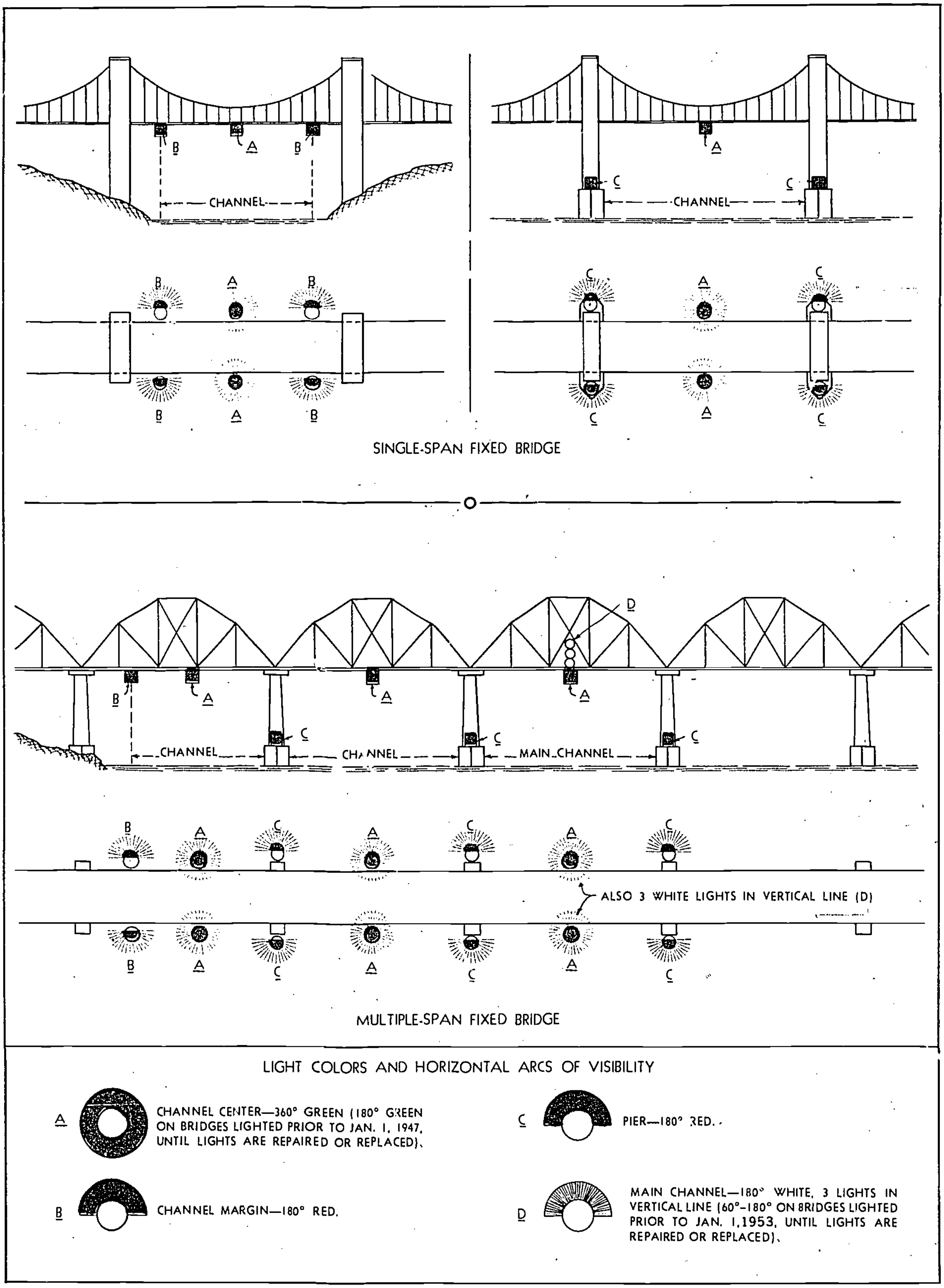
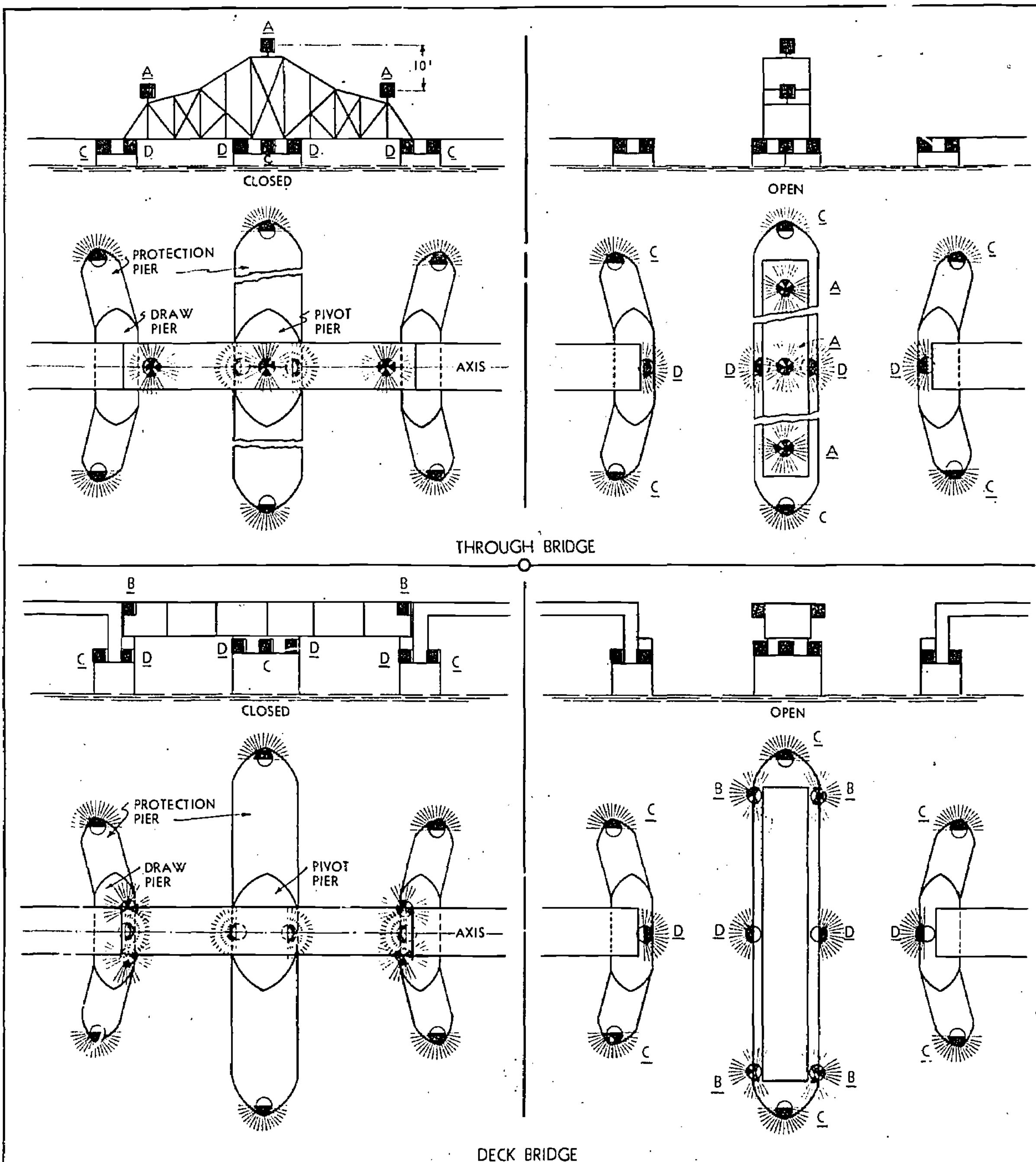



*Figure 5–127. Minimum lighting requirements for fixed bridges.*




LIGHT COLORS AND HORIZONTAL ARCS OF VISIBILITY

A — SWING SPAN—ALTERNATE RED (2) AND GREEN (2), EACH 60° AND AT 90° TO EACH OTHER.

C — PIER—180° RED.

B — SWING SPAN—ALTERNATE RED (1) AND GREEN (2), EACH 60° AND AT 90° BETWEEN RED AND GREEN.

D — AXIS—180° RED. MAY BE OMITTED WHEN DRAW AND PROTECTION PIERS ARE STRAIGHT ON THEIR CHANNEL FACES.

*Figure 5–128. Minimum lighting requirements for double-opening swing bridges.*

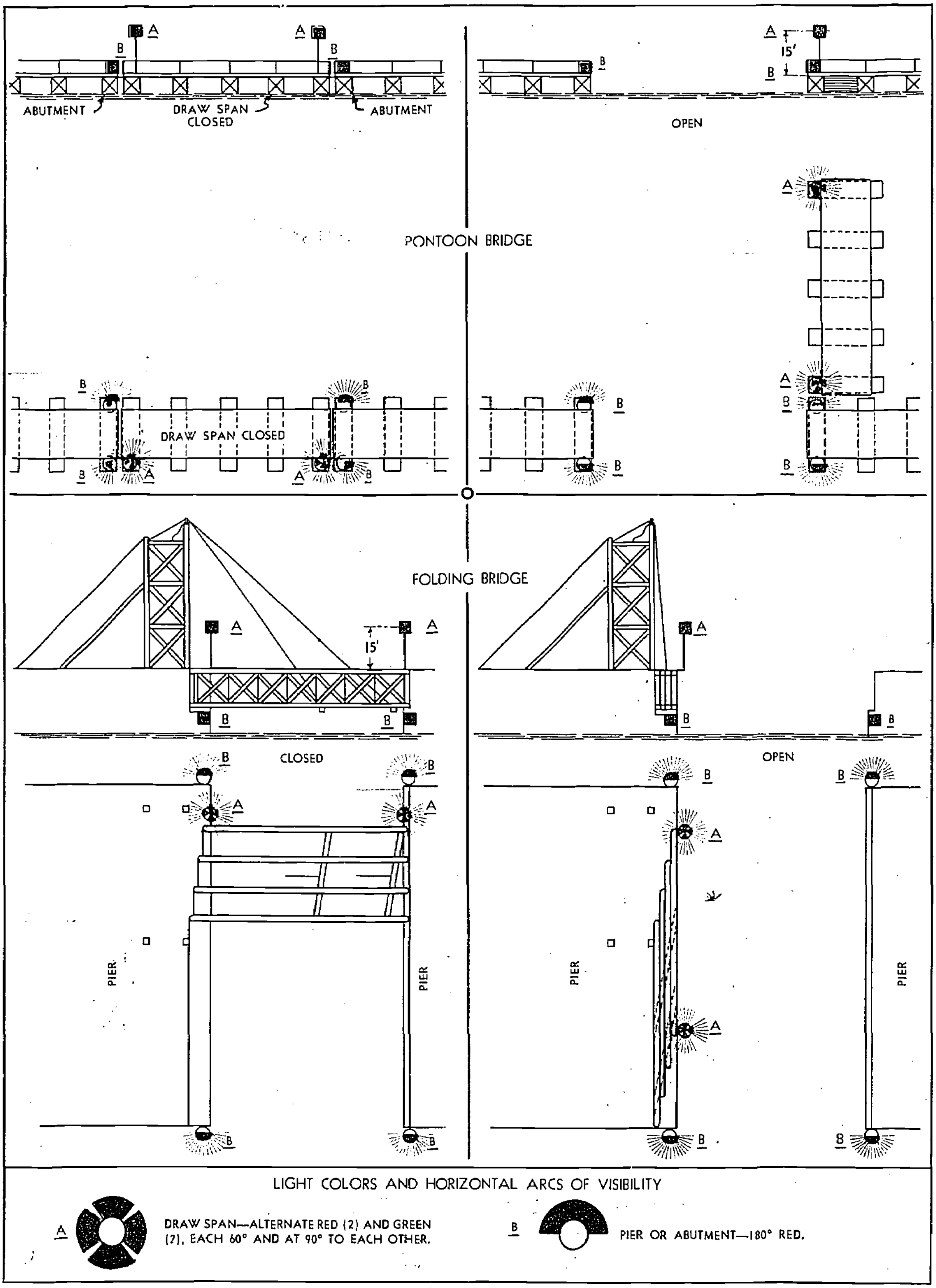



*Figure 5–129. Minimum lighting requirements for single-opening draw bridges.*

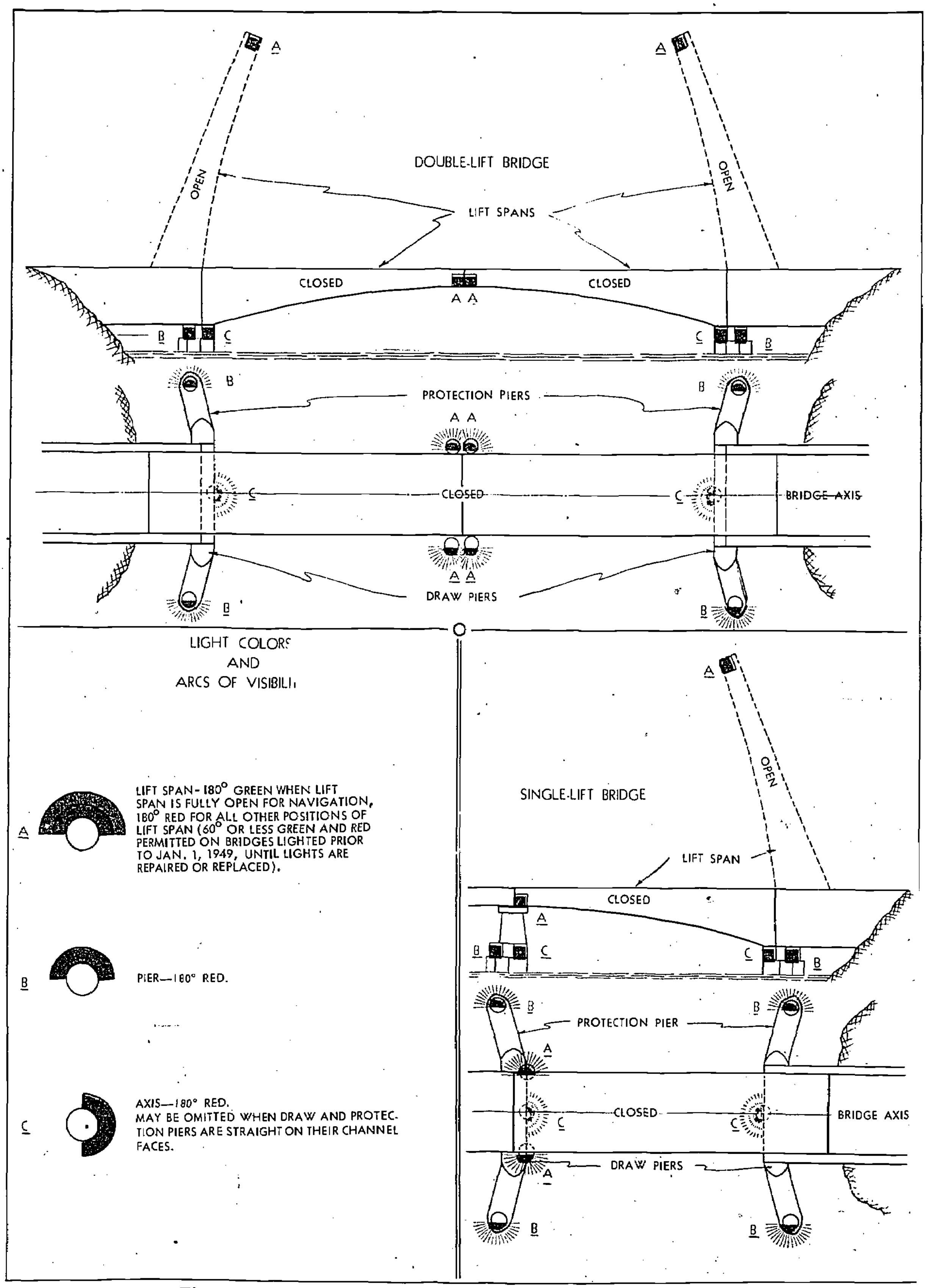



*Figure 5–130. Minimum lighting requirements for bascule bridges.*

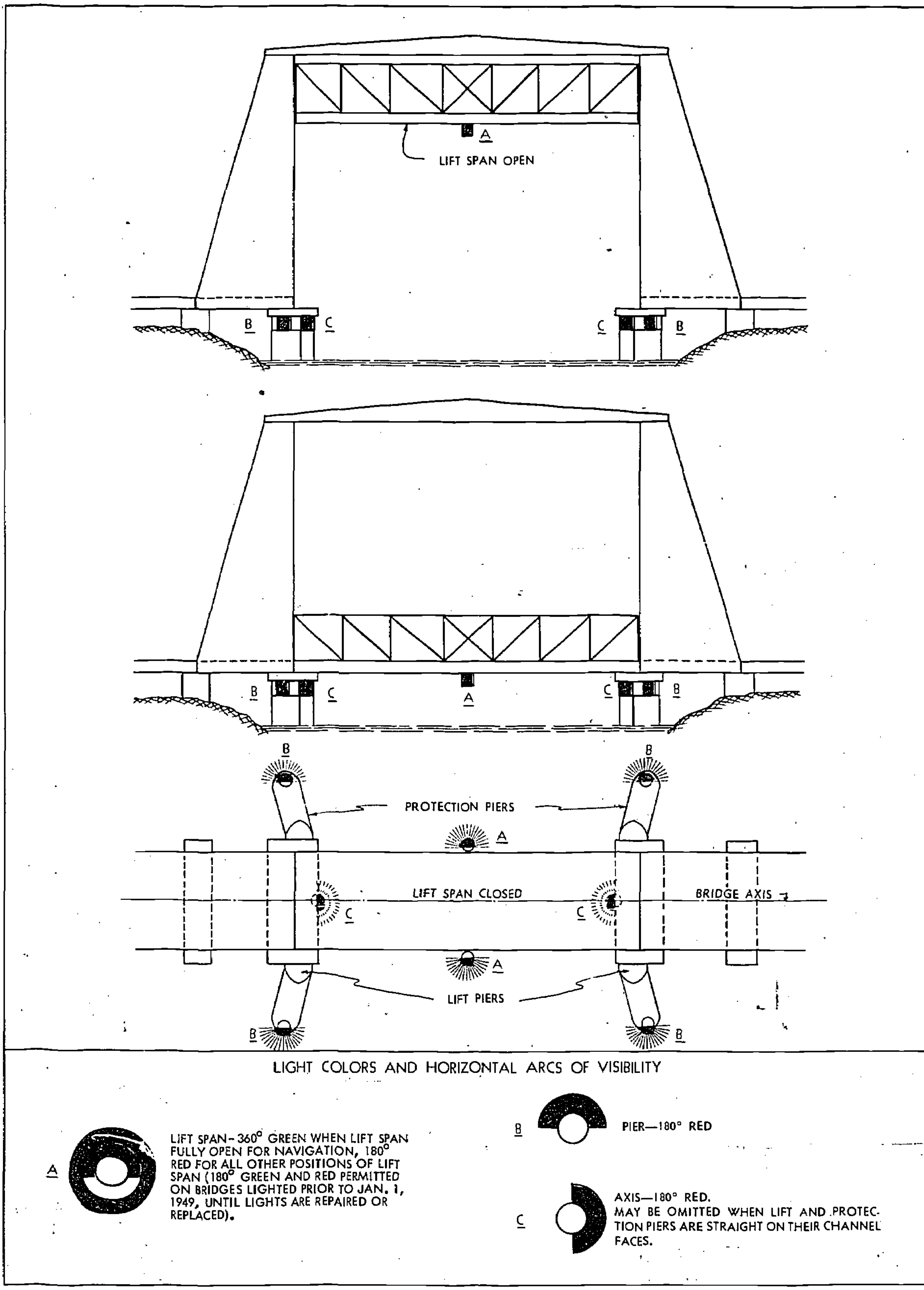



*Figure 5–131. Minimum lighting requirements for vertical lift bridges.*

(1) *Collision.* Note any light poles that are dented, scraped, cracked, inclined, or otherwise damaged.

(2) *Fatigue.* Aluminum light standards and castings are most likely to suffer from fatigue. Check for cracking in:

(a) Mast arms and cast fittings on standards.

(b) At the base of standards, especially the cast elements.

(3) *Corrosion.* Check steel standards for rusting, and concrete standards for cracking and spalling.

b. *Electrical Systems.* This part of the inspection should be made by or with the assistance of a qualified electrician.

(1) *Wiring.* Observe any exposed wiring for signs of faulty, worn, or damaged insulations. Note and report the following:

(a) Bad wiring practices.

(b) Bunches of excess wires.

(c) Loose wires.

(d) Poor wire splices.

(e) Inadequate securing of ground lines.

(2) *Junction Boxes.* Check inside junction boxes for excessive moisture, drain hole, poor wire splices, and loose connections. Note the condition of wiring and insulation. Where the base of the light standards contains a junction box, examine this as well. Note whether the junction box, outlet box, or switch box covers are in place.

(3) *Conduit.* Check conduits for rust or missing sections. Check the curbs and sidewalks for large cracks that might have fractured the conduit imbedded in them. Note whether the conduit braces and boxes are properly secured.

(4) *Whiteway Current.* On those structures where the whiteway current is carried over an open line above the sidewalks, check for hanging objects such as fishing lines and moss.

c. *Lamps or Damaged Standards.* Note any missing lamps or damaged standards. A cover placed over the electric eye controller will turn on the lights. Note the number and the locations of those lights that do not illuminate.

d. *Sign Lighting.* Inspect sign lighting for the same defects as conventional lighting.

e. *Navigation Lights.*

(1) *Lights.* Check to determine whether all of the required navigation lights are present and properly located. For fixed bridges, a green navigation light is suspended from the superstructure over the channel centerline and red lights are placed so as to mark the channel edges. When piers are situated at the channel edges, the red lights are positioned on the piers or fenders (fig. 5–127). For movable spans, navigation lighting requirements vary according to the bridge type. When in doubt as to the requirements refer to Section 68 of the Coast Guard pamphlet CG204, "Aids to Navigation." However, figures 5–128, 5–129, 5–130, and 5–131 illustrate present requirements.

(2) *Lighting Devices.* Check the overall condition of lighting devices to determine whether they are rusted, whether any of the lenses are broken or missing, and whether the lights are functioning correctly.

(3) *Wiring.* Check the condition of wiring, conduits, and securing devices to determine whether they are loose or corroded.

f. *Aerial Obstruction Lights.* For short bridges (less than 150′), these should be at least two continuous glow red lights mounted at the high points of the superstructure. For longer structures, the red lights should be placed at 150 to 600 feet intervals, while sets of at least three flashing red beacons should be mounted atop the peaks of widely separated high points such as suspension bridge towers, truss cusps, etc. Check these lights for proper maintenance and functioning.

## Section 32. MOVABLE BRIDGES

### 5–32.1 General.

Movable bridges are normally constructed only when fixed bridges are impractical or when such construction would be inordinately expensive. Three categories of movable bridges comprise over ninety-five percent of the total number of movable bridges within the United States. These categories are:

a. *Swing Bridges.* These bridges consist of two-span trusses or girders which rotate horizontally (fig. 5–132). The spans are usually, but not necessarily, equal. When open, the swing

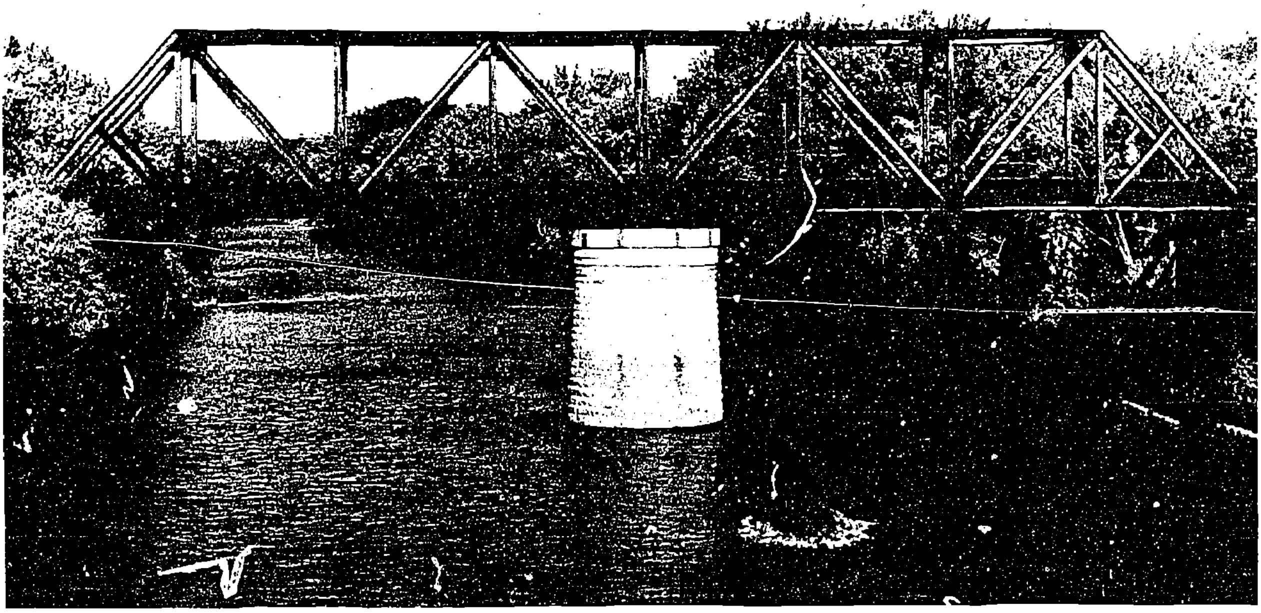


*Figure 5–132. Swing bridge.*

spans are cantilevered from the pivot (center) pier; when closed, the spans are supported at the pivot pier and at two rest (outer) piers or abutments. In the closed condition, wedges are usually driven under the outer ends of the bridge to lift them (fig. 5–133), thereby providing a positive reaction sufficient to offset any possible negative reaction from live load and impact. This design feature prevents uplift and hammering of the bridge ends under live load conditions. Swing spans are subdivided into:

(1) *Center-Bearing*. This type of swing span carries the entire load of the bridge on a central pivot (usually metal discs). Balance wheels are placed on a circular track around the outer edges of the pivot pier to prevent tipping (fig. 5–134). When the span is closed, wedges similar to those at the rest piers are driven under each truss or girder at the center pier. This relieves the center bearing from carrying any live load. However, these wedges do not raise the span at the pivot pier, but are merely driven tight.

(2) *Rim-Bearing*. This type of swing span transmits all loads to the pivot pier, both dead and live, through a circular girder or drum to bevelled rollers. The rollers move on a circular track situated inside the periphery of the pier. The rollers are aligned and spaced on the track by concentric spacer rings. This type of swing span bridge also has a central pivot bearing which carries part of the load and is connected to the rollers by radial roller shafts.

On both types of swing bridges, the motive power is usually supplied by an electric motor, although gasoline engines or manual power may also be used. The bridge is rotated by a circular rack and pinion arrangement.

b. *Bascule Bridges*. In this type of bridge the leaf (movable portion of the decks) lifts up by rotating vertically about a horizontal trunnion (axle) (figs. 5–135, 5–136, and 5–137). This trunnion is positioned at the dead load centroid. Bascule bridges may be either single or double-leafed. In the former case, the entire span lifts

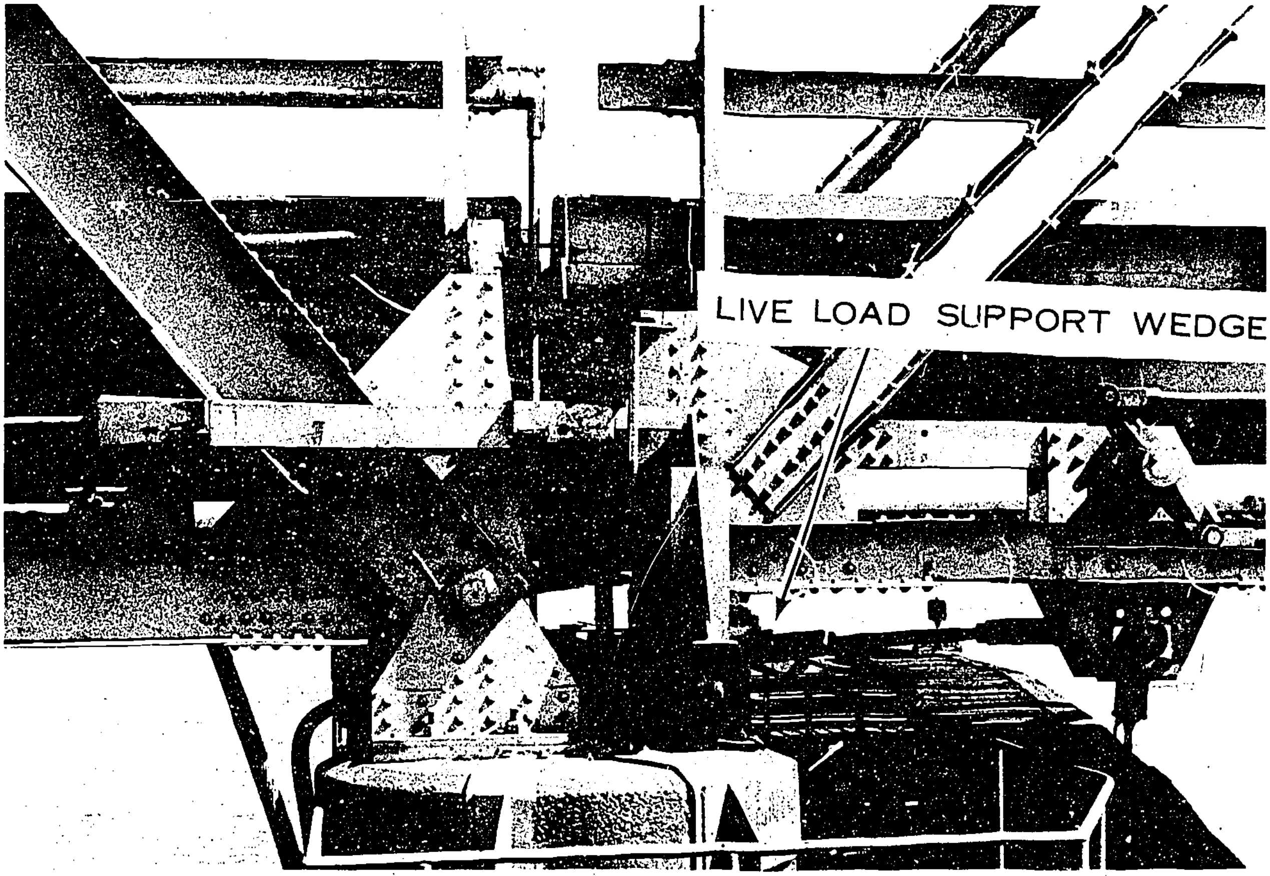



*Figure 5–133. Outer end of swing bridge on rest pier.*

about one end (fig. 5–136). A double-leafed bascule has a center joint, and half of the span rotates about each end (figs. 2–18 and 5–137). It is obvious that a counterweight is necessary to hold the raised leaf in position. In older bridges, the counterweight is overhead, while in the more modern bridge, the counterweight is often placed below deck and lowers into a pit as the bridge is opened. When the bridge is closed, a forward bearing support located in front of the trunnion is engaged and takes the live load reaction. On double-leaf bascule bridges, a tail-lock behind the trunnion and a shear lock at the junction of the two leaves are also engaged to stiffen the deck. There are several varieties of bascule bridges, but the most common are:

(1) *Chicago* (*or simple*) *Trunnion*. This variety of bascule bridge consists of a forward leaf and a rear counterweight arm which rotates about the trunnion. The trunnion bearings, in turn, are supported on the fixed portion of the bridge such as a trunnion girder, steel columns or on the pier itself.

(2) *Rolling Lift* (*Scherzer*) *Bridge*. This is a bascule bridge type whose complete superstructure, forward leaf or span itself, rear arm, and counterweight rolls back from the channel. This is accomplished with a quadrant or segmental girder whose center of rotation is at the centroid of the bascule. The girder rims roll along a toothed track and in so doing lift and withdraw the leaf. A horizontal retraction of a cable or rack attached to the centroid of the bascule leaf produces this motion.

(3) *Rall Lift*. This is a variation of the rolling lift bascule bridge in which the segmental girder is replaced by a large roller at the bascule's centroid. To open the bridge, the roller moves backward on a horizontal track.

(4) *Heel Trunnions* (*Strauss*). This class of bascule bridge employs four trunnions connecting the sides of a parallelogram-shaped panel formed by the lift span and a fixed triangular rear panel. The principal trunnion about which the movable span rotates is at the heel of the truss. Figure 5–138 illustrates the action

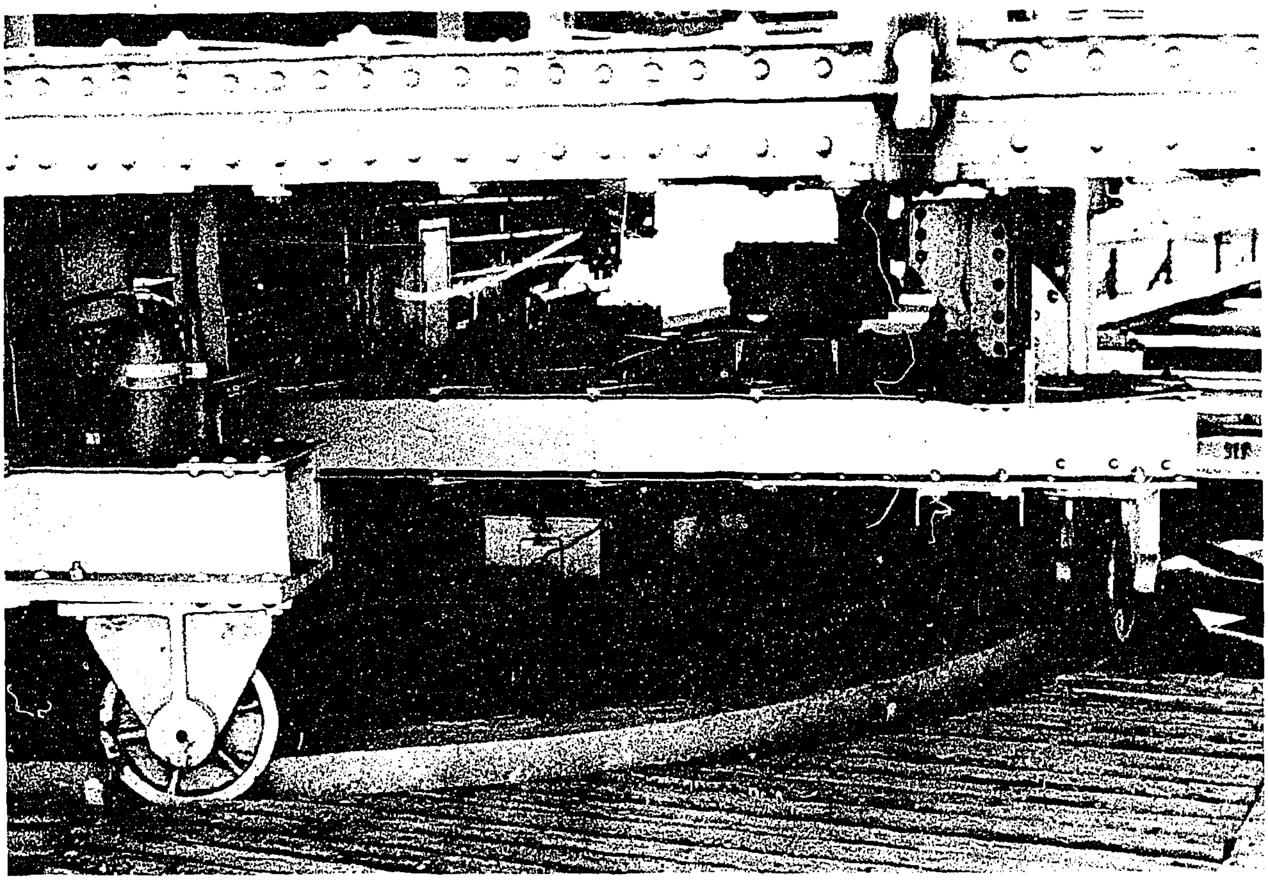


*Figure 5–134. Balance wheels and rack on center bearing swing span.*

which takes place when the movable span rotates.

All of these bridges are powered by electric motors with a rack and a pinion attachment.

c. *Vertical Lift Bridges.* These bridges have a movable span with a fixed tower or towers at each end. The span is lifted by cables at its four corners. The cables pass over sheaves (pulleys) atop the towers and connect to counterweights on the other side. The counterweights descend as the span ascends. The actual lifting of the cables is performed through the turning of drums which wind the lifting cables as they simultaneously unwind the counterweighted cables. While a number of vertical lift bridge variations can be listed, they all operate basically in the same manner as that described above.

### 5–32.2 Types of Distress Encountered in Movable Bridges.

a. Defects, damages, and deterioration typical of all steel and concrete structures can strike movable bridges, too. Therefore, most of the bridge structure defects and deterioration listed elsewhere as potential problems apply to movable spans also.

b. Mechanical and electrical equipment includes specialized areas which are beyond the scope of this manual. Since operating equipment is the heart of the movable bridge, it is recommended that expert assistance be obtained when conducting an inspection of movable spans. It should be noted that in many cases, the owners of these movable bridges follow excellent programs of inspection, maintenance, and repair.

c. Fatigue can be a problem with movable bridges due to the reversal or the fluctuation of stress as the span opens and closes. Any member or connection subject to such stress variations should be carefully inspected for fatigue failure.

d. Swing bridges are probably most susceptible to the following deficiencies:

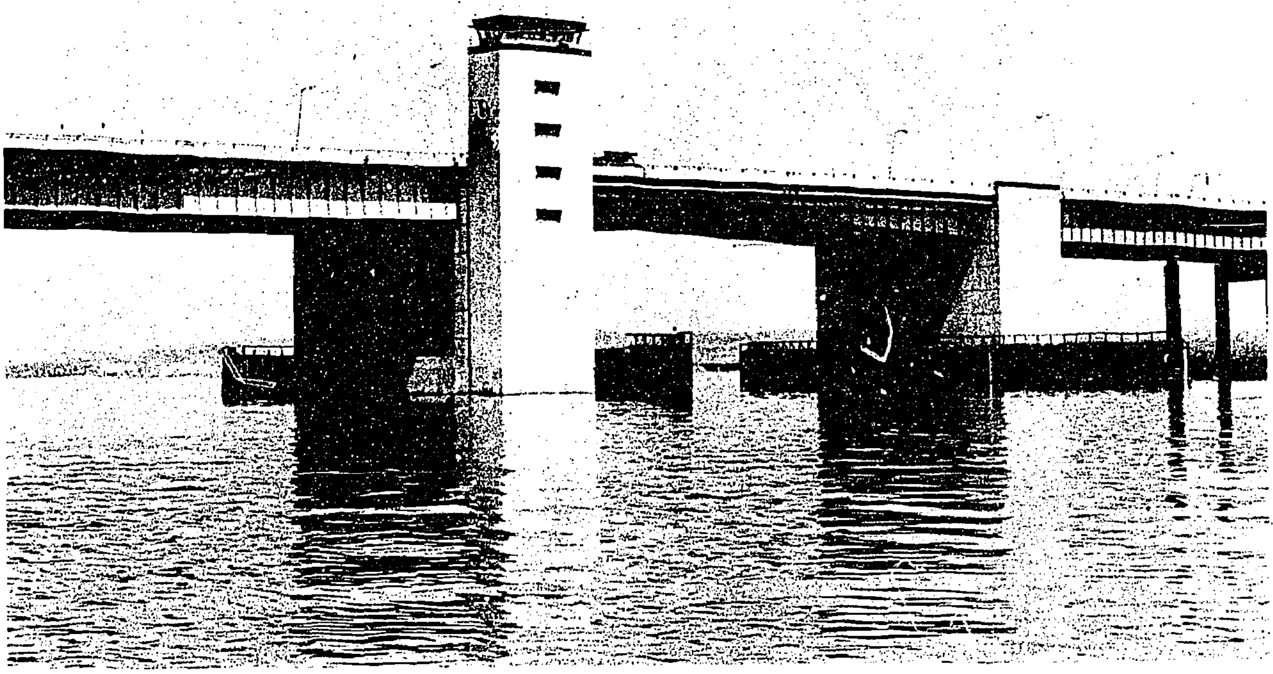


*Figure 5–135. Bascule bridge..*

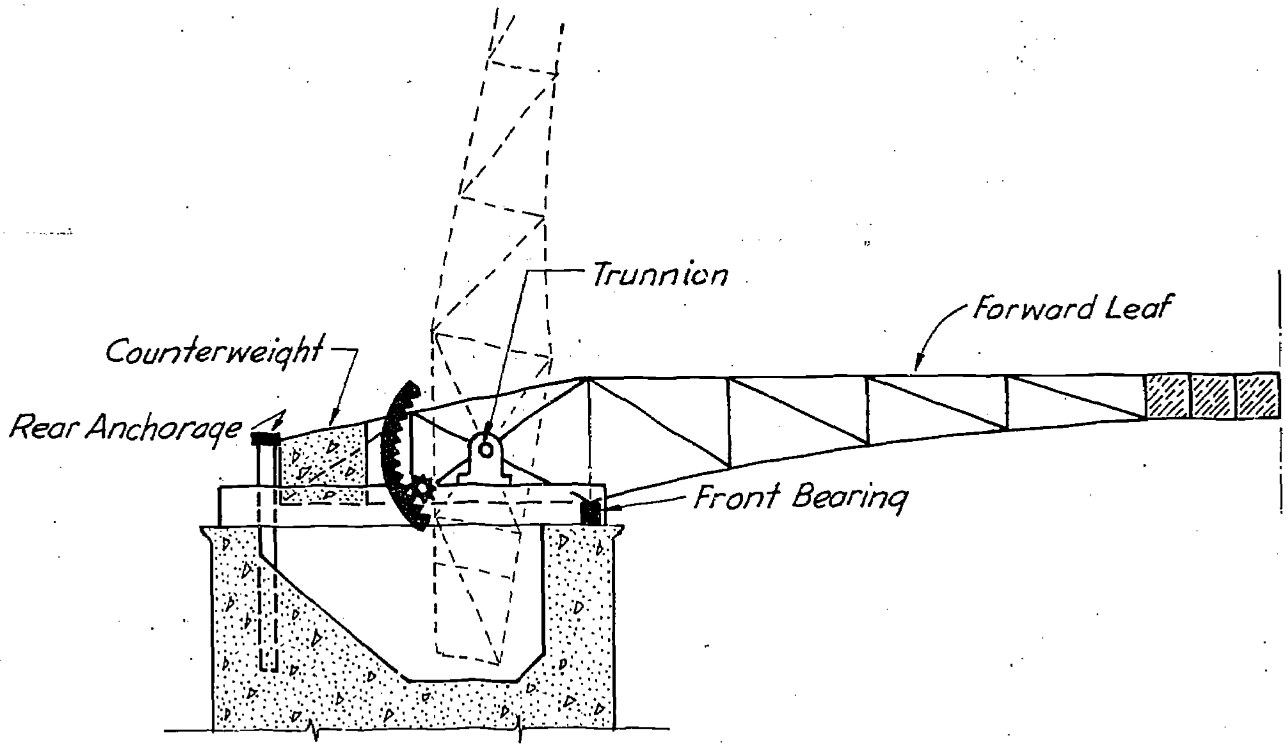



*Figure 5–136. Trunnion bascule bridge.*

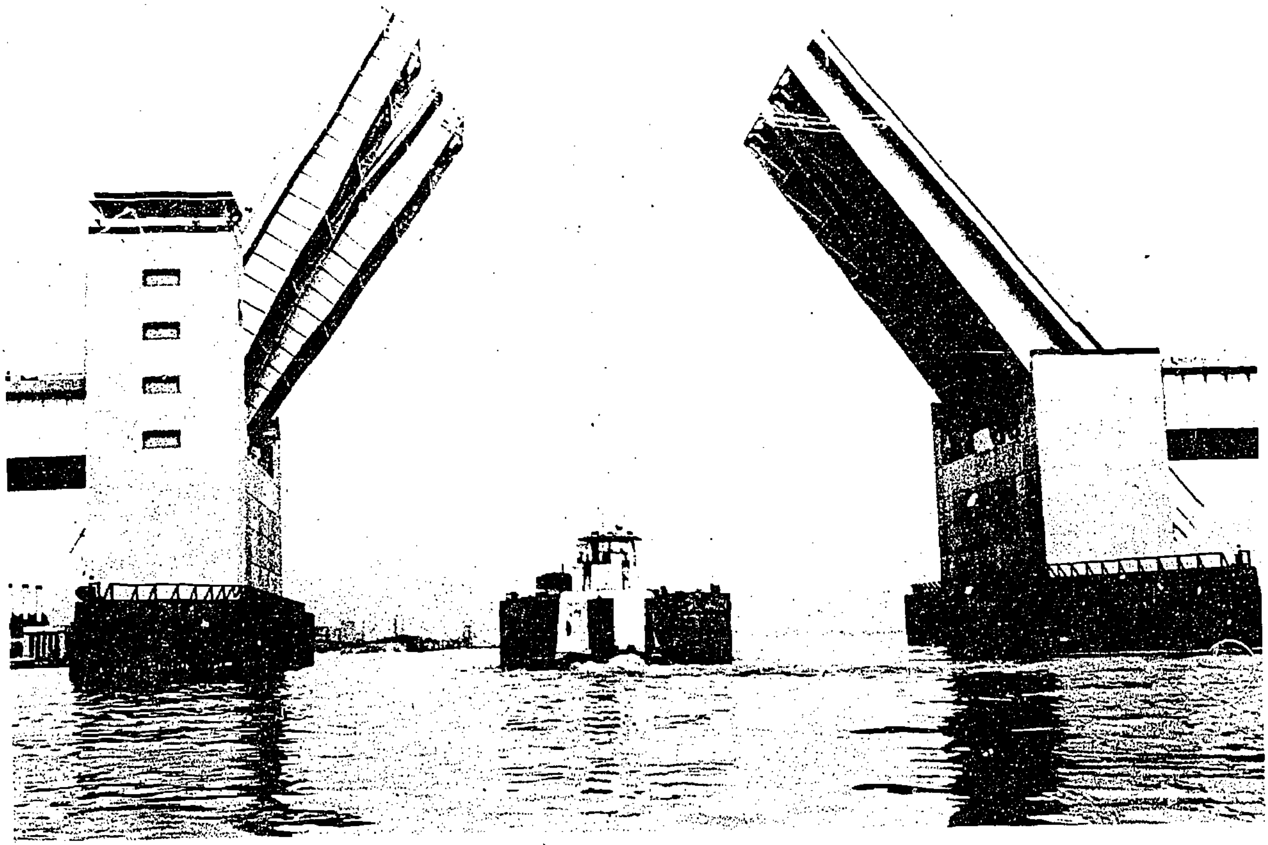
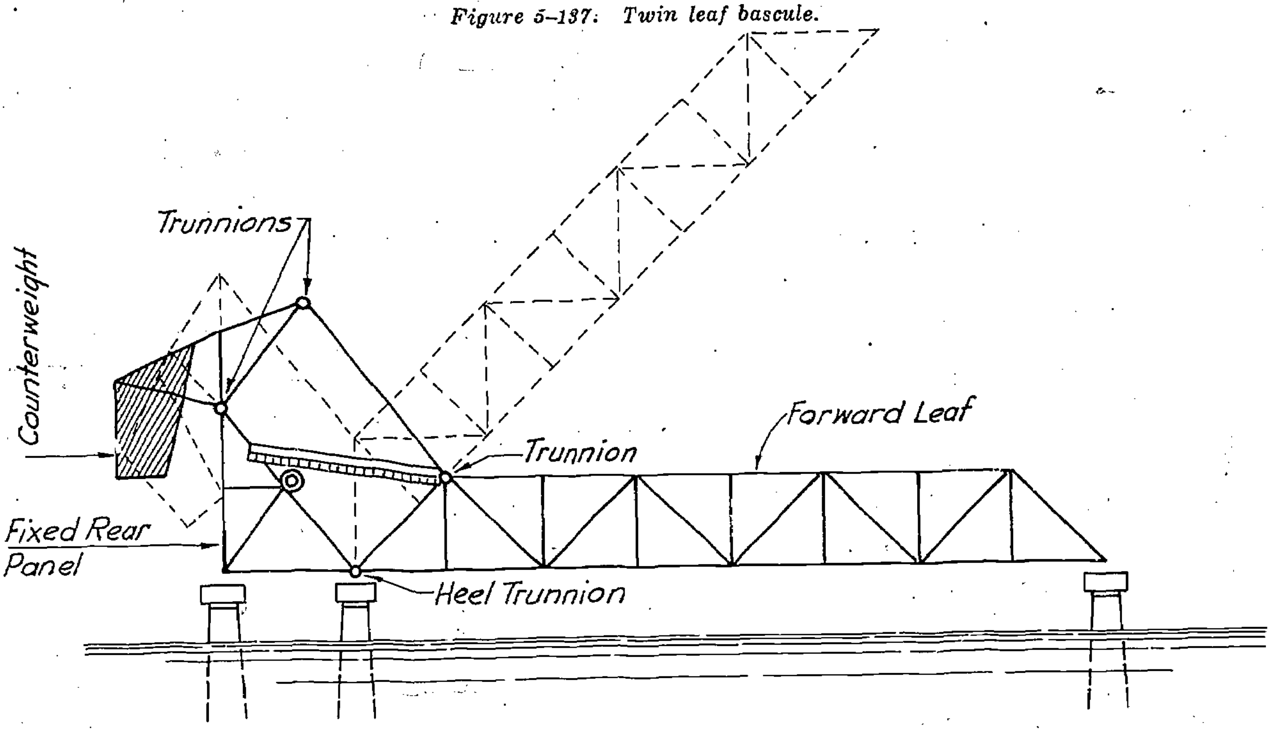


*Figure 5-137. Twin leaf bascule.*




*F[illegible] Heel trunnion bascule bridge.*

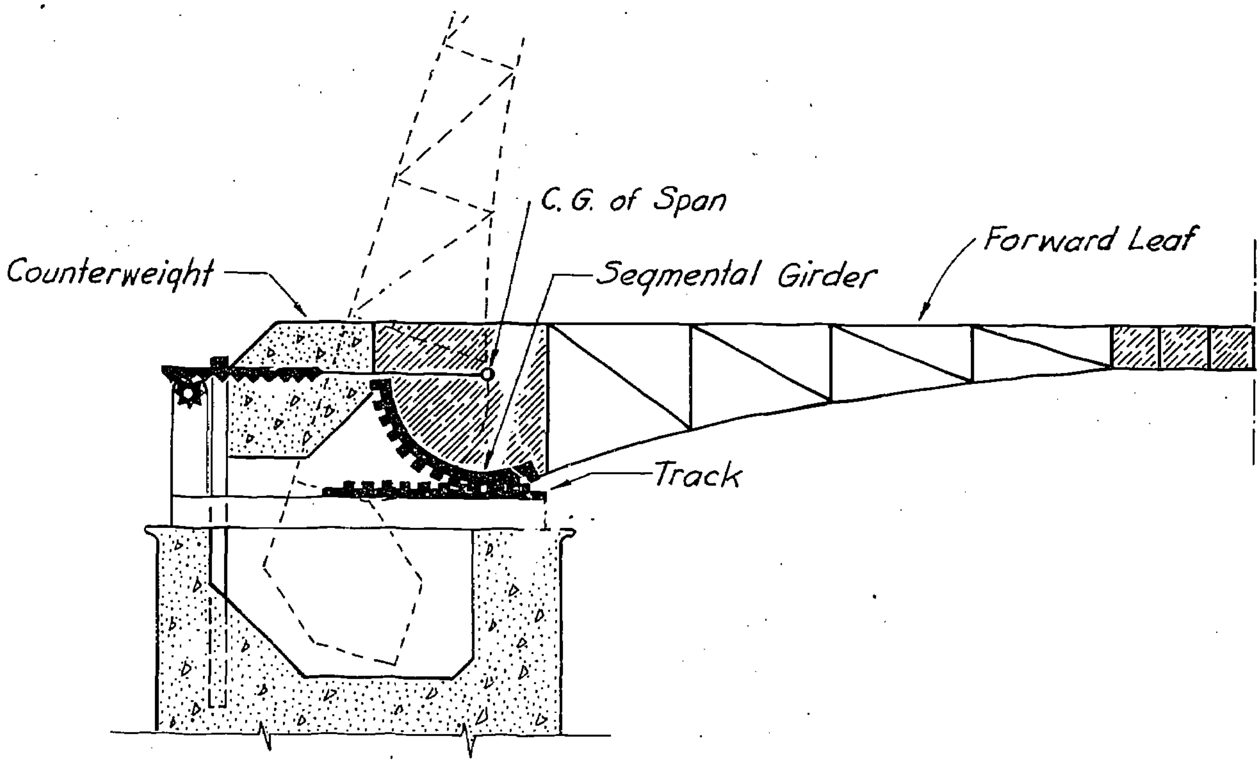



*Figure 5–139. Rolling-lift bascule bridge.*

(1) Structural fatigue.

(2) Maladjustment of the outer bearings and of the live load bearings at the pivot pier (on center bearing swings). This could cause uplift at one end of the swing span, hammering of the bridge upon the rest piers, and excessive strain or wear upon the center bearings.

(3) Wear of the discs in the center bearing.

(4) Distortion of the rim bearings on the pivot pier. The outside rollers may crowd inward or outward, developing horizontal forces on the center pivot. This may result in loosening of the pivot or in destructive wear.

(5) Worn and maladjusted span locks on the rest piers.

e. *Bascule Bridges.*

(1) *Center Lock.* This device is designed to transmit shear at mid-span between the two leaves of a double-leaf bascule, and is usually some form of an interlocking key and slot arrangement. Although some bridges lock by a simple meshing process, most are likely to employ a movable piston. Should the tongue or slot become worn, the increased play in the lock will allow vibration and deflection.

(2) *Segmental Girder and Track on Rolling Lift Bridges.* Figure 5–139 illustrates a rolling lift bascule bridge. These bridge features frequently cause maintenance problems. The repeated pressure exerted between the rolling girders and the tracks will cold work the girder or the track, causing an extension of one of the plates. Where a toothed track is used, rolling will be hampered. Where smooth plates are used, the segmental girder may lengthen, causing binding at the rear joint. Sometimes the track may flatten, warping the member to which it is connected and causing fatigue cracking.

(3) *Front Load Bearings.* When these bearings are out of adjustment live load forces can shift to the main trunnion causing overstress and increased wear.

(4) *Bascule Main Leaf Girders.* Since it is not possible to describe all types of bascules, it should be noted that many of these bridge types transfer the full reaction from the trunnion bearings to the substructure by means of large girders, floor beams, or heavy bracings. In such cases, the members that are exposed to these stresses should be inspected carefully for signs of distress or corrosion.

(5) *Trunnions.* A trunnion and its bear-

ings constitute the focal point of the leaf's rotation and as such are subject to deflection and wear, either of which can impair the operational efficiency and/or safety of the bridge.

f. *Vertical Lift Bridges.* Check the condition of the cables and determine whether they have freedom of movement.

### 5–32.3 What to Look for During Inspection.

a. *General.*

(1) *Cables.* Counterweight cables as well as uphaul and downhaul cables on lift or bascule spans should be inspected carefully for wear, damage, corrosion, and evidences of inadequate lubrication. To properly inspect cables, old lubricant must be removed. After inspection, the cable should be relubricated. Check for any binding at the travel rollers and guides. Check the piers for rocking when the leaf span is lifted.

(2) *Counterweights and Attachments.*

(a) Check the counterweights to determine if they are sound and are properly affixed to the structure. Further check temporary supports for the counterweights that are used during bridge repair.

(b) Where steel members pass through, or are embedded in the concrete, check for any corrosion of the steel member and for rust stains on the concrete.

(c) Look for cracks and spalls in the concrete.

(d) Check for debris, animals, and insect nests in the counterweight blocks.

(e) Where cable counterweights (balance chains) are employed, check links, slides, housings, and storage areas for deterioration, for adequacy of lubrication, where applicable, and for protection.

(f) Determine whether the bridge is balanced and whether extra weight blocks are available. A variation in the power demands on the motor, according to the span's position, is an indicator.

(g) Paint must be periodically removed from the lift span proper; otherwise, the counterweights will eventually be inadequate.

(3) *Drainage.* Check to determine whether the counterweight is properly drained. On vertical lift bridges be sure that the sheaves and their supports are well drained. Examine any portion of the bridge where water can collect.

(4) *Piers.* Check the piers for rocking when the leaf is lifted. This is an indicator of a possible serious deficiency and should be reported at once.

(5) *Warning Devices.*

(a) Check the operation of safety gates, barriers, and warning signals. Be sure they function properly and that the warning signals give sufficient notice to permit vehicles to clear the automatic gates.

(b) Determine whether manually operated safety gates should be converted to mechanically operated gates.

(c) Determine whether the safety gates and barriers are sound and well maintained. Note any decayed areas at bolt and other connections. Note whether either needs to be replaced or repaired.

(d) Note the locations of the safety gates in relation to the warning light signs and bells, and the bridge opening itself. Check the warning lights with regard to location to determine whether they can be easily seen by motorists.

(6) *Aids to navigation.* Lights and fenders are very important, and should be inspected as discussed in Sections 25 and 31 of this chapter. Clearance gauges shall be inspected for visibility and legibility.

(7) *Trunnion girders.* Examine all main trunnion girders and floor beams for buckling or cracking due to overstress or fatigue.

(8) *Trunnions and bearings.* These should be checked for weakness, excessive play, corrosion, and undesirable deflection or bending.

(9) *Machinery.* On all movable structures the machinery is so important that considerable time should be devoted to its inspection. The items covered and termed as machinery include all motors, gears, tracks, shafts, linkages, overspeed control, brakes, and any other integral part that transmits the necessary power to operate the movable portion of the bridge. The inspection of the next ten items and items similar to them should be made by a machinery or movable bridge specialist.

(a) Check the alignment of all gears, locks, and other interlocking mechanisms.

(b) Check the adequacy of the lubrication of all movable parts, particularly where meshing or contact occurs between the movable parts. Also check the schedule of lubrication to determine whether the frequency of lubrication is sufficient.

(c) On live load bearings, check the wedge (lock) linkages for loose knee pins and for excessive play. Note the closing and the releasing of the wedge locks or pin locks for proper functioning.

(d) Check all gears for cracks including the teeth, spokes, and the hub.

(e) Inspect all shafts for twisting, strain, and for play within bearings.

(f) Check the keyways on the shafts and the gears for looseness. Check the keys for looseness also.

(g) Check the braces, bearings, and all the housings for cracks especially where welded joints occur.

(h) Inspect the concrete for cracks in areas where machinery bearing plates or braces are attached. Note the tightness of bolts and the tightness of other fastening devices used.

(i) Check all brake devices for proper functioning.

(j) Check to see whether stops are used or needed.

(10) *Motors and Engines*. The inspection of motors and engines should be made by mechanical specialists. The inspection should include the check of the following conditions:

(a) If a belt drive is used, check for wear and slippage. Note the condition of all belts and the need for replacement, if any.

(b) If a friction drive is used, check for wear and for uneven bearing areas.

(c) If a direct drive is used, check all bracings and bearings for tightness.

(d) If a liquid coupling is used, check the fluid to ascertain that the proper quantity is used. Look for leaks.

(e) In movable bridges, check the flexible cable to the motor.

(11) *Grid Decks*.

(a) Check structural welds for soundness and the grid decks for skid resistance.

(b) Check roadway surface for evenness of grade and for adequate clearance at the joints where the movable span meets the fixed span.

(12) Conduct trial openings as necessary to insure proper operational functioning and that the movable span is properly balanced. Trial openings should be specifically for inspection. During the trial openings, the safety of the inspection personnel should be kept in mind.

b. *Swing Bridges*.

(1) Check the wedges and the outer bearings at the rest piers for maladjustment. This can be recognized by excessive vibration of span or uplift when load comes upon the other span.

(2) Check the live load wedges and bearings located under the trusses or girders at the pivot pier for proper fit.

(3) Check the teeth of all gears for wear and for proper alignment. The meshing of gears should be checked so as to determine whether gears are climbing one upon the other.

(4) On center bearing swings, check the center pivot, the housing, the tracks, and balance wheels for fit, wear, pitting, and cracking. Check for proper and adequate lubrication.

(5) On rim bearing bridges inspect the center pivots, the rollers and the roller shafts, and the guide rings or tracks for proper fit, wear, pitting, and cracking. Check for proper and adequate lubrication.

c. *Bascule Bridges*.

(1) Check the center locks on double-leafed spans, and note whether there is excessive deflection of the center joint or vibration on the bridge. Inspect the locks for fit and for movement of the leaf (or leaves). Check lubrication and loose bolts. Check the lock housing and its braces for noticeable movement. This can be done by observing the paint adjacent to it for signs of paint loss or wear.

(2) Check the differential vertical movement at the joint between the two leaves under the passage of heavy loads.

(3) Check the joint between the two leaves for adequate clearance.

(4) Check the front live load bearings to determine whether they fit snugly. Also observe the fit of tail-locks at rear arm and of support at outer end of single leafers.

(5) Check the bumper blocks and the attaching bolts for cracks at the concrete bases.

(6) Check the counterweight well for excess water. Check the condition of the sump pump, the concrete for cracks, and the entire area for debris.

(7) Check the brakes, limit switches, and stops (cylinders and others) for excessive wear and slip movement. Note whether the cushion cylinder ram sticks or inserts too easily.

(8) Check the shaft or trunnion bearings for excessive wear, lateral slip, and loose bolts.

(9) Check shear locks for wear. Excessive movement should be reported and investigated further.

(10) On rolling lifts, check segmental rim and girder, and the track plate and girder for:

(a) Extension of rim plates and track plates in either direction.

(b) Wear and poor fit of toothed rim and track plates, including cracking in the corners of the slots in the rim plates and fractured teeth.

(c) Distortion of rim and track plates including curling of edges and separation of plates from their supporting girders.

(d) Cracking at the fillets of the angles forming the flanges of the segmental and track girders.

(e) Cracking of the concrete under the track.

(f) Looseness between walking pinion gear and top rack. Check top rack for lateral movement when bridge is in motion.

(g) On heel trunnion (Strauss) bascules, check the strut connecting the counterweight trunnion to the counterweight for fatigue cracks. On several bridges, cracking has been noted in the web and lower flanges near the gusset connection at the end nearer the counterweights. The crack would be most noticeable when the span is opened.

(h) The rack and pinion should be inspected for gear wear, cleanliness and corrosion.

d. *Vertical Lifts.*

(1) Check span and counterweight guides for proper fit and free movements. Span guides are usually castings attached to suspended span chords which engage a T-section attached to the tower. Counterweight guides are angles or tees attached to the tower and engaging grooved castings attached to the counterweights. These grooved castings must be inspected closely for wear in the grooves. Check cable hold-downs, turnbuckles, cleats, guides, clamps, and splay-castings.

(2) Check motor mounting brackets to ensure secure mounting.

(3) Check alignment and wear of cables, drums, and sheaves. Note whether cable is running properly in sheave grooves. Recommend the replacement of all frayed or worn cables. Look for any obstructions to proper movement of cables through pulleys, etc.

(4) Check spring tension, brackets, braces, and connectors of power cable reels.

(5) Check travel rollers and guides, brakes, limit switches, and stops.

(6) Since the machinery room is usually under the main deck, check the ceiling of the machinery room for leaks or areas that allow debris and rust to fall on the machinery.

(7) Survey lift bridges, including towers, to check both horizontal and vertical displacements. This should identify any foundation movements that have occurred.

e. *Control House.*

(1) Consult with the bridge operator to ascertain whether there are any changes from the normal in the operation of the bridge.

(2) Note where the control panel is located in relation to roadway and waterway.

(3) Note whether the bridge tender has a good line of sight view of approaching boats and vehicles.

(4) Note whether structure shows cracks. Determine whether it is wind-proof and insulated.

(5) In some cases only control boxes are provided without a bridge tender. Note this situation and check the security system.

(6) If controls are separate, note description of bridge tender's house or shed, and include its condition as well as the information about the control house.

(7) Note whether all Coast Guard, Corps of Engineers and local instructional bulletins are posted.

(8) Note whether alternate warni..g devices such as bull horns, lanterns, flasher lights, or flags are available.

(9) Check for obvious hazardous operating conditions involving the safety of the operator and maintenance personnel.

(10) Check for any accumulations which may be readily combustible.

(11) Check controls and electric panels on movable structures. An electrical specialist should be available for this part of the inspection.

(a) Check controllers while bridge is opening and closing. Look for excess play and sparks. Check electrical cabinets for loose wires, heaters and bunched-up wires. Note debris or material hidden in cabinets.

(b) Inspect the electrical system of the bridge including the wiring, conduits, motors, and lights.

(c) Check for worn or broken lines.

(d) Check for any existing hazardous condition.

(e) Check for rusted-out or mismatched members.

(f) Determine whether the controller is outdated or parts need replacement.

(g) Determine whether electrical interlock is working.

(h) Check whether panel doors are secured.

(i) Note whether bridge tender has any complaints about the panel.

(j) Check span speed control resistor banks for overheating.

(12) Check the bridge operator's log.

f. *Storage Facilities.* Check all storage facilities for flammable material and any accumulation which may be readily combustible.

g. *Main and Submarine Cables.*

(1) *Main cables.*

(a) Note the condition of the power lines coming to the bridge.

(b) Where high voltage lines come all the way to a transformer in the control house, check that the main lines or cables are fully insulated and out of reach of the public.

(c) Where transformers are on a power pole near the bridge, check the rigidity of the pole, guy lines, ground line, and cable to bridge.

(d) Check the transformer in the control house, if any, for bracing, high voltage cables insulation loss, leaks, and cable protection.

(e) If a cable is attached to the bridge, check anchors, clips, concrete bases, insulators, or armor, for attached growth or debris.

(f) Determine whether the line or transformers should be replaced or relocated.

(g) Check lightning arrester device for signs of distress.

(2) *Submarine Cables.*

(a) Indicate the size and number of conductors in the submarine cable. This is very important. Indicate the number of conductors being used, the number of spares that are available, and the number of conductors that have failed. This should equal the total number of conductors in the cables.

(b) Note whether the cable is protected from boats and the public, and whether it is behind the fender system.

(c) Note whether the cable is kinked, hooked, or exposed either above or below the water.

(d) Note whether the ends are conditioned and protected from moisture.

(e) Check the cable at tidal areas for excess marine or plant growth.

(f) If cable has been spliced, note condition of box seal.

(g) Inspect clamps and securing clips.

h. *Auxiliary Power.*

(1) Operate auxiliary power or crank and note condition and reliability.

(2) On double leaf bascules, note whether both sides have axiliary power systems.

(3) On hand cranked systems:

(a) Determine whether standing platforms are free of grease and debris.

(b) Determine the number of men needed in this operation.

(c) Determine whether a portable generator powered mechanical device can replace the manpower needed to operate the bridge.

## Section 33. UNDERWATER INVESTIGATIONS

### 5–33.1 General.

Underwater investigation is a highly specialized area. This type of bridge investigation is outside the normal duties of the bridge inspector. Whenever underwater investigations are necessary they should be conducted by the personnel experienced in these types of inspections.

However, the bridge inspector is still responsible for the bridge inspection and for the evaluation of the underwater portions of the bridge. The importance of such inspections on trestle and pile bent bridges cannot be overestimated. Relatively new structures have collapsed due to the corrosion of the steel piles below the concrete protection. Prestressed concrete piles are not immune to failures below water level, while timber piles are also known to be vulnerable. Investigation of such corrosion, or other deterioration, is especially important in sea water, which is four times as deleterious as fresh water.

### 5-33.2 What to Look for During Inspection.

a. *Pile Bents.* Check piles of all materials below the water line for any signs of deterioration or damages.

(1) *Steel Piles.* Steel piles are susceptible to corrosion in the splash zone and tidal zone, and have been found to be severely perforated at deeper water depths. Where piles are concrete-jacketed in the tidal zone, the diver should carefully check for signs of corrosion from the area just below the concrete jacket all the way down to the mud line.

(2) *Timber Piles.* Timber piles should be observed carefully from the water level to the mud line for marine borer and shipworm attacks on timber pilings.

(3) *Prestressed Piles.* Check prestressed piles for longitudinal cracking. Pay particular attention to hollow prestressed piles.

(4) *Piles Under Piers.* The above instructions also apply to piles under piers where the footing is set above the river or harbor bottom.

b. *Dolphins and Fenders.* Dolphins and fenders should be examined below the water for deterioration and borer attack, and for any damage caused by vessels or large floating objects.

c. *Pier and Abutment Conditions.* Where the substructures are exposed below water, they should be examined for any deterioration of the concrete or of the rubble masonry piers, for loss of protective stone facing, and for any indication of pier movements.

d. *Scour.* The river bottom around the piers or abutments should be checked for development of scour holes, unintended exposure of piling, and the condition and effect of any scour control installations. However, it is preferable to conduct scour investigations from the surface, if possible.

e. *Underwater Cables.* Cables should be investigated for the following:

(1) Damage to the cable from vessels or floating objects.

(2) Kinks in the cable.

(3) Exposure of the cable when it should be buried.

(4) Age and condition of the cable, and any need for replacement.

(5) If the cable location is not as charted, plot the current cable location.

### 5-33.3 The Diver.

Diving confronts a diver with forces and physiological effects which are not encountered in his normal environment. Each type of diving equipment and operation gives rise to unique demands for safety precautions. The diver's safety depends upon his knowledge of the factors which constitute safe working conditions, and upon his ability to recognize unsafe conditions. While diving operations will normally be conducted and supervised by specialist personnel, it is incumbent upon the bridge inspector to assist in these operations in whatever way possible. In order to assist the diver in his duties:

a. Define exactly what bridge components the diver is to inspect.

b. Ensure that he is thoroughly aware of what inspection task or tasks he is to accomplish.

c. Provide him with any reference data, such as previous inspection reports, which may be helpful.

d. Prepare, as much as practical, the bridge inspection site beforehand. Often a substantial amount of marine growth and barnacles can be cleaned from piles, and other areas to be inspected, by working from a boat.

e. Ensure that a boat, with a trained crew, is ready.

## Section 34. SUSPENSION SPANS

### 5–34.1 General.

Suspension bridges are normally constructed only when the more conventional types of bridges are impractical because of clear span requirements or because the use of intermediate piers is not feasible. Suspension bridges may be categorized by the method of anchorage used, the type of cable used, or a combination of both.

a. *Anchorage.*

(1) *Conventional or Independent Anchorages.* These bridges rely on anchoring ends of the cables by using either massive blocks of concrete or masonry, or by tunneling into rock.

(2) *Self-Anchored.* These bridges have no means for massive external anchoring of the main cable. The main cables of these bridges are anchored by redirecting the horizontal component of the cable pull back into the bridge structure itself. However, a portion of the vertical cable reaction is absorbed by the anchor piers.

b. *Cable.*

(1) *Parallel Wire.* This type of bridge is supported by main cables made up of a series of parallel wires spun in place, compressed and wrapped.

(2) *Prefabricated Bridge Strand.* This type of bridge is supported by main cables made up of a series of bridge strands (either parallel or twisted wire), fabricated, stretched, and socketed in the shop and then shipped to the bridge site on reels. These strands are erected one at a time; they may or may not be wrapped.

(3) *Eye Bar Chain.* This type of bridge is supported by main chains made up of a series of eye bars connected with pins. There are few bridges of this type remaining in this country.

c. *Suspension Bridge Components.* The discussion in paragraph 5–34.2 will be limited to the cable and its connections only. All other bridge components will be inspected in detail as covered in other sections of this manual under their respective types.

### 5–34.2 What to Look for During Inspection.

a. *Anchor Bars or Rods.*

(1) Check all anchor bars or rods at the face of their concrete embedment for possible corrosion, deterioration, or movement.

(2) Check the entire visible (unencased) portion of the anchor chain for corrosion or signs of distress.

b. *Strand Shoes.* Check the strand shoes on parallel wire type bridges for signs of displaced shims, movement, corrosion, misalignment, and cracks in the shoes.

c. *Strand Sockets.* Check the strand sockets at the anchorages of prefabricated strand type bridges for signs of movement, slack or sag, corrosion, broken sockets, and unpainted or rusty threads at the face of sockets. Unpainted or rusty threads may indicate possible "backing off" of nuts.

d. *Wires in Anchorage.* In parallel wire type bridges, check the unwrapped wires between the strand shoes and the splay saddle by carefully inserting a large screwdriver between the wires and applying leverage. This test will reveal the presence of broken wires for some distance past the splay saddle under the wrappings. (Only random checking is required.)

e. *Strands at Anchor Sockets.* Check the strand at its entrance to the socket for signs of possible abrasion, corrosion, or movement.

f. *Main Suspension Cables.* Check for corroded wires. Examine the condition of the protective covering or coating of the main suspension cables, especially at:

(1) Areas adjacent to the cable bands.

(2) Saddles over towers, cable bent piers and at anchorages.

g. *Splay Saddles.* Check the splay saddles for:

(1) Missing or loose bolts.

(2) Movement up the cable away from the splay. Signs of this movement may be the appearance of unpainted strands on the down hill side or "bunched up" wrapping on the uphill side.

(3) The presence of cracks in the casting itself.

h. *Cable Bands.* Check the cable bands for:

(1) Missing or loose bolts.

(2) Possible slippage. Signs of this movement are caulking that has pulled away from the casting or "bunching up" of the soft wire wrapping adjacent to the band.

(3) The presence of cracks in the band itself.

(4) Broken suspender rope saddles.

(5) Corrosion or deterioration of the band.

(6) Loose wrapping wires at the band.

i. *Saddles.* Check saddles for:

(1) Missing or loose bolts.

(2) Slippage of the main cable.

(3) Corrosion or cracks in the casting.

(4) Connection to top of tower or supporting member.

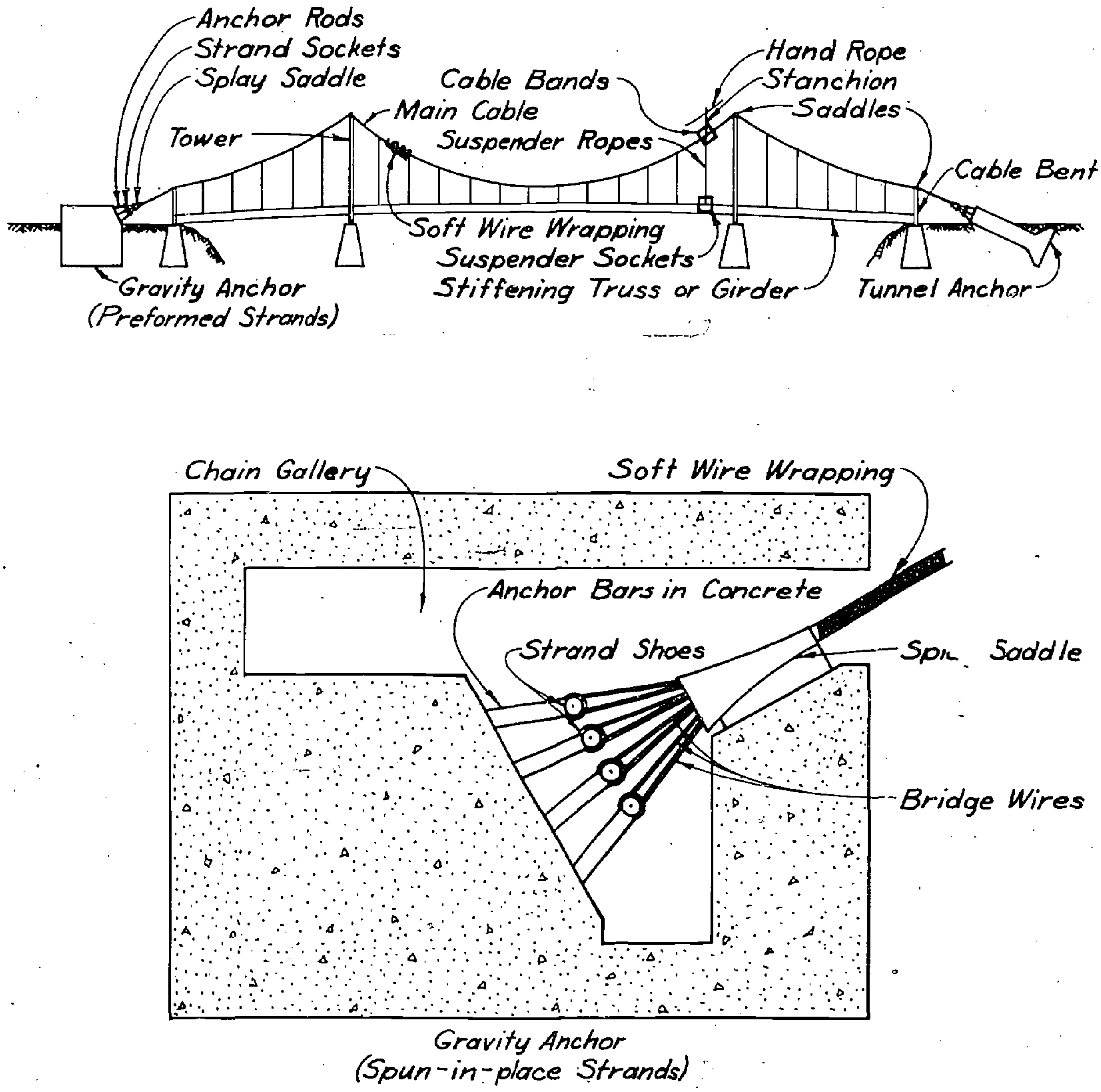



*Figure 5–140. Suspension bridge features.*

j. *Hand Ropes and Connections.* Check hand ropes and connections for:

(1) Loose connections of stanchion to cable bands.

(2) Too much slack in rope.

(3) Bent or twisted stanchions.

(4) Loose connections at anchorages or towers.

(5) Corroded or deteriorated ropes or stanchions.

k. *Suspender Ropes.* Check suspender ropes for:

(1) Corrosion or deterioration.

(2) Kinks or slack.

(3) Abrasion or wear at sockets, saddles, clamps, and spreaders.

(4) Broken wires.

l. *Suspender Rope Sockets.* Check sockets for:

(1) Corrosion, cracks, or deterioration.

(2) Abrasion at connection to bridge structure.

(3) Possible movement.

m. *Anchorages.* The anchor chain gallery of the anchorage is usually a dark damp enclosure with a very corrosive atmosphere. The interior should be inspected for the following:

(1) Corrosion and deterioration of any steel hardware.

(2) Protection against water entering or collecting where it may cause corrosion.

(3) Proper ventilation.

n. *Wrapping Wire.* Check to see that there are no loose wrapping wires or cracks in the caulking where water can enter and cause corrosion of the main cable. Check for evidence of water seepage at cable bands, saddles and splay castings.

# CHAPTER VI

# REPORTS AND RECOMMENDATIONS

## Section 1. REPORTS

### 6–1.1 Introduction.

In the preceding chapter the factors, conditions, and situations which cause bridge deterioration were described in considerable detail. The intent of this chapter is to outline the objectives of bridge inspection reports, discuss generally the uses of bridge inspection reports, and emphasize the importance of preparing practical documented recommendations for actions to be taken, based upon the specific bridge inspection finding.

### 6–1.2 Reports.

a. *General.* The bridge inspection report is an extremely valuable document when completed properly. A new inspection report should be made each time a bridge is inspected. To achieve maximum effectiveness, each report should be supplemented with sketches, photographs, or any other additional explanatory information. Reports and supplemental information must be accurate, and amplifying descriptions or explanations should be clear and concise. A well prepared report will not only provide information on existing bridge conditions but also becomes an excellent reference source for future inspections, comparative analyses, and for bridge study projects. Whenever confronted with a doubtful condition not overtly manifested as a defect or deficiency, but nevertheless suspicious, it should be reported. In doing so, however, the bridge inspector must be careful to report the circumstances factually and avoid speculation, exaggeration, or supposition. Further action on such reports will be determined after review and consultation by higher engineer authorities.

b. *Report Objectives.* The purpose of systematic periodic bridge inspections, and the additional inspection of bridges immediately following any natural or man-caused occurrence which might have lessened the structural integrity of a bridge, is to:

(1) Provide an information base for immediate action to limit the use of, or to close to traffic, any bridge which inspection has revealed to be hazardous to public safety.

(2) Determine the extent of any weakness or structural damage, critical or minor, resulting from normal deterioration or from any other cause.

(3) Develop a chronological record of the conditions of the bridge, thus providing a basis for analyzing the significance of structural changes.

(4) Enable bridge maintenance to be programmed more effectively through early detection of structural defects or deficiencies, thus minimizing repair costs.

(5) Maximize public safety through the elimination or correction of hazardous conditions.

(6) Assist in the replacement programming of bridge structures.

### 6–1.3 Uses of Bridge Inspection Reports.

a. Bridge inspection reports provide an informational record of the current analyses of similar bridge structures including such matters as, but not limited to:

(1) Traffic density and its effects.

(2) Nature, frequency, and extent of repairs by type.

(3) Safety records.

(4) Specific kinds of deterioration.

(5) Preventive maintenance programs.

b. Inspection reports of themselves are insufficient to guarantee the continued safe service of the bridge. If the ultimate objective of a bridge inspection program is to be achieved, it becomes necessary to:

(1) Make a structural analysis of the bridge to ascertain its safe load capacity for its current condition.

(2) Restrict loads crossing the bridge so that its computed safe capacity is not exceeded.

(3) Perform all maintenance necessary to prevent a decline in the load capacity of the bridge or to increase the bridge capacity to a minimum essential level.

(4) Eliminate all known or suspected hazards to public safety.

## *Section 2. RECOMMENDATIONS*

### 6–2.1 General.

a. A good inspection report will explain in detail the type and extent of any deterioration detected on a bridge, and will point out any deviations or modifications that are contrary to the "as built" construction plans of the bridge. Not all conditions of deterioration are of equal importance. For example, a crack in a concrete box beam which allows water to enter the beam is much more serious than a vertical crack in the backwall, or a spall in a corner of a slopewall. The inspector, in formulating his recommendation, must determine the seriousness of the defect or deficiency involved. He must carefully consider the benefits to be derived from making the repairs, the cost involved, and the consequences if the suggested repairs are not made. Following this he must judiciously weigh these considerations in arriving at reasonable and practical conclusions.

b. The recommendations made by the inspector constitute the "focal point" of the operation of inspecting, recording, and reporting. A thorough, documented inspection is essential for making practical recommendations on suggested courses of action to correct or preclude bridge defects or deficiencies. Theoretically, if there are no recommendations, there is nothing seriously wrong with the bridge structure.

### 6–2.2 Categories of Repair.

Recommendations concerning repairs may be classified into two general categories:

(1) Urgently needed repairs, or

(2) Programmed repairs, those to be performed sometime later.

The inspector must decide whether a repair is urgent. Usually this is easily determined, but at other times the experience and professional judgment of a graduate engineer may be required to reach a proper decision. A rapidly enlarging hole through the deck of a bridge obviously needs attention, and a recommendation for emergency repair is in order. By contrast, a slightly deteriorated gusset plate at a panel point of a truss may not be critical. A condition such as this would appropriately call for a recommendation for a programmed repair. Whenever emergency repairs are needed, recommendations may call for repairs of a temporary nature. For example, a steel plate may be positioned in place over a hole in the deck, or a damaged beam may be supported temporarily with timber. It must be realized, however, that any temporary repair must later be integrated into the annual maintenance program on the basis of established orders of priority for work completion. It may be recommended that repairs be made on a permanent basis, if such repairs can be completed as quickly and as efficiently as any available temporary means. Most recommendations concerning repairs submitted by the bridge inspector will be in the category of programmed repairs; i.e., repairs that will be incorporated into preprogrammed repair and maintenance schedules. Figure 6–1 portrays how inspection report recommendations might be processed.

### 6–2.3 Cost Considerations.

a. Whenever an inspector recommends that bridge repairs be made, he may describe fully the type of repairs that are needed, the scope of work to be done, an estimate of the materials that will be required to complete the proposed repairs, and when such repairs may be undertaken. Such information will be used to determine:

(1) The priority for repair, and
(2) The method of repair.

More important, the cost of such repairs must be reviewed and analyzed in the context of the overall maintenance repair program.

b. In order to arrive at the most effective, yet economical, means of accomplishing repairs, it is imperative that a comparison be made between alternatives. The availability of funds may determine the type and extent of repairs and will influence the priority of work assigned. If the recommended repairs are already programmed, then it must be decided whether the repairs can be accomplished as previously scheduled. If not, then the schedule needs to be modified accordingly. Again, the element of cost is a deciding factor since even the administrative process of changing the order of scheduled repairs involves costs. In addition, the delay of already scheduled repairs may result in added

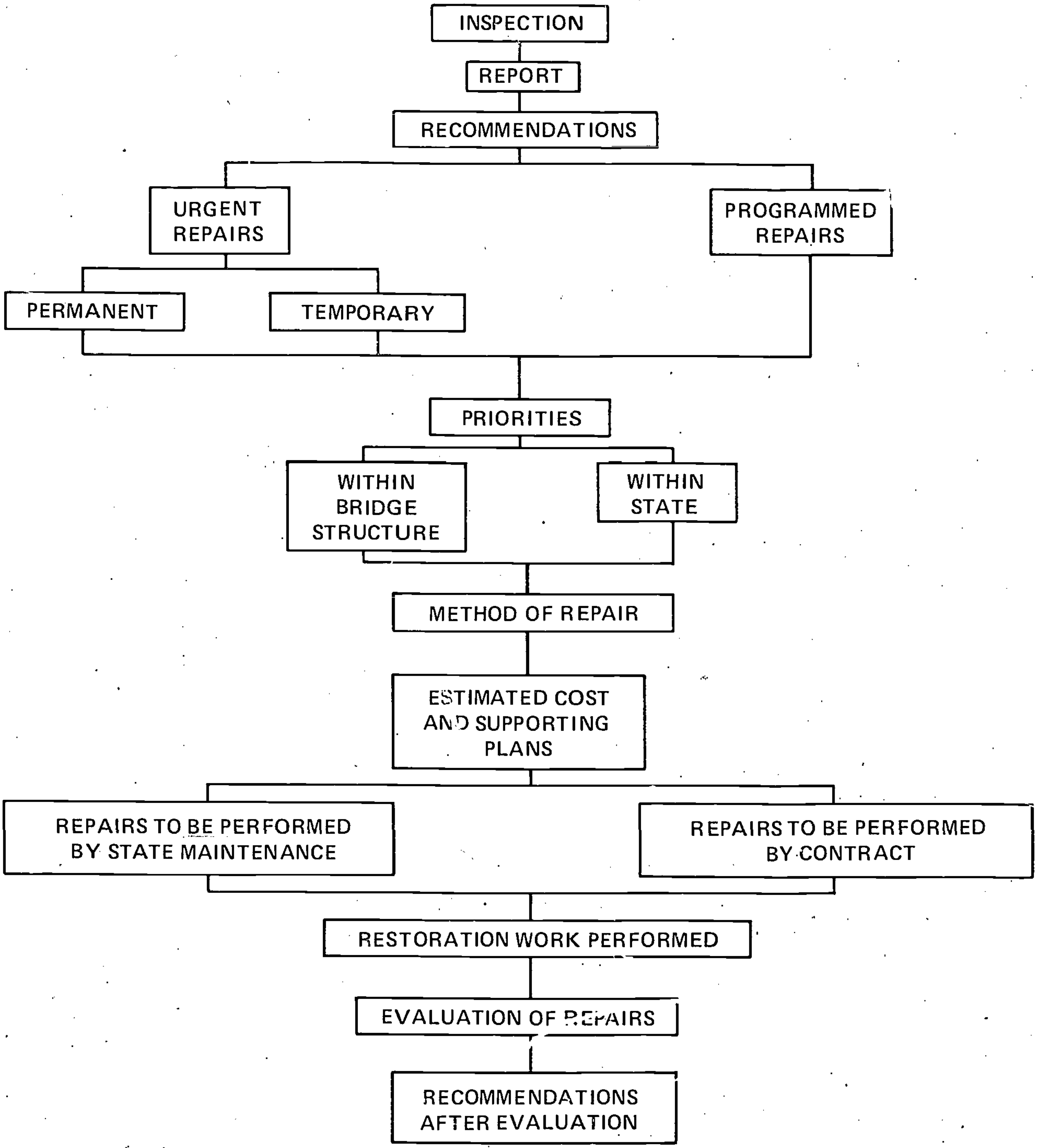



*Figure 6–1. Typical repair recommendation process.*

costs since the conditions which were to be corrected by such repairs may have become worse.

c. The priority given to recommended repairs may be one of urgency; however, the press of other equally urgent repairs may dictate a reassessment of priorities and a review of available repair capabilities. If organizational repair capabilities are unable to fulfill all repair requirements, contractural arrangements may have to be made. Should this course of action be followed, costs become a deciding factor. Everyone concerned should strive for that combination of organization and contract capability which will provide for effective bridge repair at a reasonable cost. Whatever course of bridge repair action is pursued, the prime dictate of such action should be in the interest of public safety and public investment.

**6–2.4 Priorities.**

a. Priorities of repair are determined by a number of factors in addition to engineering considerations. It may also be important to weigh environmental, economic, and social factors. Although in many cases the priority will be set by one individual, the information supplied by several persons will be instrumental in reaching a sound decision. Priorities should be established on a statewide basis, as well as within a smaller geographical area, such as a district.

b. The following considerations should be taken into account in the establishment of priorities for bridge repair.

(1) *Factors.*

(a) *Safety.* Any condition which is considered unsafe, either from a structural (e.g., disintegrated pier cap) or user (e.g., weakened railing) viewpoint, should be assigned a high priority for correction.

(b) *Condition of Structure.* The most important factor in establishing repair priorities is the degree of deterioration of the structure. It is essential for the inspector to provide complete and accurate data in order to permit a valid analysis of the structure.

(c) *Density of Traffic.* Where bridge deterioration is approximately equivalent, a higher priority probably should be assigned to the bridge serving the greater density of traffic. The priority rating should be upgraded if there is a high percentage of heavy load traffic.

(d) *Alternate Bridges.* Lack of convenient alternate bridges should upgrade the priority of repairs.

(e) *Weather.* Defects that would be aggravated by adverse weather should be corrected prior to the onset of extreme weather conditions.

(f) *Traffic Fluctuations.* If a bridge must be partially or totally closed for repairs, this should be done when traffic density is relatively low.

(g) *Bridge Size.* The size of any bridge is an indication of its overall importance; therefore, bridge size will influence the priority ranking for repairs.

(h) *Geographical Location.* Occasionally it may be economical to modify priorities for reasons of location. For instance, if two or more bridges are located in close proximity and require similar repairs, it may be more practical to complete these bridges consecutively irrespective of established priorities. Thus, bridges ranked 8 and 11 according to a priority of repair might be repaired consecutively if bridges 9 and 10 are comparable to them in degree of deterioration.

(i) *Replacement.* Any priority rating for bridge repairs should consider whether the bridge in question is scheduled for replacement and when closure or restricted access, if any, is to be effected. A bridge scheduled for replacement in the near future may warrant only temporary repair or, possibly, none at all depending on the nature of the repairs.

(2) *Intra-Structure Priorities.* An order of priorities within each individual bridge structure may also be established based upon structural importance and degree of deterioration. It is preferable to list the various items that need repair according to structural significance. Such a listing will permit the report reviewer to determine immediately what the most serious defects are, and will assist him in ordering the priority of repairs for that structure.

**6–1.5 Summary.**

Methods and standards for the inspection of bridges, while not universal in application, have, nevertheless, been established through experience. These methods and standards have been developed, modified, and refined for the purpose of preserving the integrity of the bridge structure in the interests of public safety and service. Chapter V. pointed out the characteristics of those conditions which cause deterioration and which the inspector should be keenly aware of during the course of his inspection routine. Obviously, the bridge inspector cannot be a superficial observer. Whenever the bridge inspector is engaged in the task of inspecting and assessing the conditions of any bridge, he must be thorough in his application of bridge inspection techniques. His investigations must be complete and his findings conscientiously recorded in detail. Those conditions which are currently or potentially injurious to the bridge, regardless of how small or seemingly unimportant they may appear, must also be included in his report of inspection.

The importance of well-formulated and documented recommendations cannot be over stressed. Their content provides the basis for: (1) the elimination of hazards to public and bridge safety, (2) remedial repairs, and (3) the elimination of inadequacies affecting the bridge. Therefore, it is incumbent upon the bridge inspector, whenever the occasion arises, to prepare meaningful recommendations which can be clearly and easily understood.

# GLOSSARY

## A

**Abutment.** A substructure composed of stone, concrete, brick, or timber supporting the end of a single span or the extreme end of a multispan superstructure and, in general, retaining or supporting the approach embankment placed in contact therewith. Figure 5–36. (See also RETAINING WALLS, WING WALLS.)

The following types are now commonly used:

**Cantilever Abutments.** An abutment in which the stem or breast wall is fixed rigidly to the footing. The stem, acting as a cantilever beam transmits the horizontal earth pressure to the footing, which maintains stability by virtue of the dead weight of the abutment and of the soil mass resting on the rear portion, or heel, of the footing.

**Cellular Abutment.** An abutment in which the space between wings, breast wall, approach slab, and footings, instead of containing the approach fill, is hollow. This amounts to an R/C box or boxes comprising the abutment. On some bridges curtain walls are placed between the pier and abutment to simulate a cellular abutment.

**Counterforted Abutment.** An abutment which develops resistance to bending moment (or horizontal force) in the stem by use of counterforts. This permits the breast wall to be designed as a horizontal beam or slab spanning between counterforts, rather than as a vertical cantilever slab.

**Gravity Abutment.** A heavy abutment which resists the horizontal earth pressure by its own dead weight.

**Integral Abutment.** A small abutment cast monolithically with the end diaphragm of the deck. Although such abutments usually encase the ends of the deck beams and are pile supported, spread footings with a combination backwall and end diaphragm may also be used.

**L-Abutment.** A cantilever abutment with the stem flush with the toe of the footing, forming an L in cross section.

**Spill-Thru Abutment.** Consists essentially of two or more columns supporting a grade beam spanning the space between them. The approach embankment is retained only in part by the abutment since the embankment's sloped front and side portions extend with their normal slope to envelop the columns. Also called an arched abutment.

**Shoulder Abutment.** (*Full-Height Abutment.*) A cantilever abutment extending from the grade line of the road below to that of the road overhead. Usually set just off the shoulder.

**Semi-Stub Abutment.** Cantilever abutment founded part way up the slope, intermediate in size between a shoulder abutment and a stub abutment.

**Straight Abutment.** (*Trapezoidal or Block.*) An abutment whose stem and wings are in the same plane or whose stem is included within a length of retaining wall. In general, the stem wall is straight but will conform to the alignment of the retaining wall.

**Stub Abutment.** (*Perched Abutment, Dwarf Abutment.*) An abutment within the topmost portion of the end of an embankment or slope and, therefore, having a relatively small vertical height. While often engaging and supported upon piles driven through the underlying embankment or in-situ material, stubs may also be founded on gravel fill, the embankment, or natural ground itself.

**Aggregate.** The sand, gravel, broken stone, or combinations thereof with which the cementing material is mixed to form a mortar or concrete. The fine material used to produce mortar for stone and brick masonry and for the mortar component of concrete is commonly termed "fine aggregate" while the coarse material used in concrete only is termed "coarse aggregate."

**Allowable Unit Stress.** See STRESS.

**Anchorage.** The complete assemblage of members and parts whether composed of metal, masonry, wood or other material designed to hold in correct position the anchor span of a cantilever bridge, the end of a suspension span cable or a suspension span backstay; the end of a restrained beam, girder or truss span; a retaining wall, bulkhead, or other portion or part of a structure.

**Anchor Span.** The span which in conjunction with the uplift resisting anchorage device (if any) located at its outermost end, counterbalances and holds in equilibrium the fully cantilevered portion or arm extending in the opposite direction from the major point of support. See CANTILEVER BEAM, GIRDER, OR TRUSS.

**Anchor Bolt.** A bolt-like piece of metal commonly threaded and fitted with a nut, or a nut and washer at one end only, used to secure in a fixed position upon the substructure the end of a truss or girder, the base of a column, a pedestal, shoe, or other member of a structure. The end intended to engage the masonry may be formed in various ways depending somewhat upon the conditions attending its setting in final position. Among these are the following:

**Hooked.** Bent either cold or in a heated condition to form a hook-like anchorage. The hooked bolt is commonly built into the masonry preliminary to the placing of the member to be anchored and it may, therefore, be utilized to engage an anchor bar or other device imbedded in the masonry.

**Ragged, Barbed or Fanged.** Cut with a chisel to produce fin-like projections upon the surface.

**Threaded.** Shaped with a machine-cut thread. The thread anchorage is commonly supplemented by a nut, or a nut and anchor plate, when the bolt is to be built into the masonry instead of being set in a drilled hole.

**Swedged.** (*Notched, Hacked.*) Indented and bulged by swedging or nicked transversely and diagonally, or both, by cutting with a chisel.

**Angle of Repose.** (*Angle of Internal Friction.*) As applied to approach embankments or other earthwork construction: the batter or slope angle with the horizontal at which a given earth material will slide upon itself from a higher to a lower elevation. At all angles less than the angle of repose, the particles of earth are held in equilibrium by the forces of gravity and friction. Relatively slight variations in the quantity of contained moisture produce marked differences in the angle of repose. The inclined surface of a cut or of an embankment either naturally or artificially produced at the angle of repose is commonly described as being at "natural slope."

**Anisotropy.** The property of some engineering materials, such as wood, exhibiting different strengths in different directions.

**Approach Slab.** A heavy R/C slab placed on the approach roadway adjacent to and usually resting upon the abutment back wall. The function of the approach slab is to carry wheel loads on the approaches directly to the abutment, preventing the transfer of a horizontal dynamic force through the approach fill to the abutment stem.

**Apron.** A waterway bed protection consisting of timber, concrete, riprap, paving or other construction placed adjacent to substructure abutments and piers to prevent undermining by scour.

**Arch.** In general, any structure producing at its supports reactions having both vertical and horizontal components. However, this definition is not intended to include structures of the rigid frame type, although applicable thereto, but instead to apply only to those having throughout their length a curved shape, either actual or approximated.

Specific types of arches adapted to bridge construction derive their names either from the form of curve (or combination of curves assumed for the development of their intradosal surfaces), the support conditions, or their type of construction. The following constitute a portion of the types in use:

**Elliptic Arch.** One in which the intrados surface is a full half of the surface of an elliptical cylinder. This terminology is sometimes incorrectly applied to a multicentered arch. (An elliptic arch is fitted to stone masonry arches.)

**Circular Arch.** One in which the intrados surface is a portion of the surface of a right circular cylinder.

**Multi-Centered Arch.** One in which the intrados surface is outlined by two or more arcs having different radii by intersection tangentially and disposed symmetrically.

**Open Spandrel Arch.** An arch having spandrel walls with its spandrel unfilled. The arch ring receives its superimposed loads through these walls and, if necessary, through interior spandrel walls, tie or transverse walls, and/or interior columns.

A structure having the spandrel walls replaced by bays or panels with arches, lintel spans, or other constructions supporting the deck construction and these in turn supported by cross walls or columns resting upon the arch ring. See OPEN SPANDREL RIBBED ARCH.

**Open Spandrel Ribbed Arch.** A structure in which two or more comparatively narrow arch rings function in the place of an arch barrel. The ribs are rigidly secured in position by arch rib struts located at intervals along the length of the ring. The arch rings support a column type open spandrel construction sustaining the floor system and its loads.

**Parabolic Arch.** One in which the intrados surface is a segment of a symmetrical parabolic surface (suited to concrete arches).

**Spandrel Arch.** A stone or reinforced concrete arch span having spandrel walls to retain the spandrel fill or to support either entirely or in part the floor system of the structure when the spandrel is not filled.

**Segmental Arch.** An arch in which the intrados surface is less than half of the surface of a cylinder or cylindroid. Likewise it may take shape wherein any right section will show a parabolic curvature.

**Two-Hinged Arch.** An arch which is supported by a pinned connection at each support.

**Three-Hinged Arch.** An arch with end supports pinned and a third hinge (or pin) located somewhere near mid-span making the structure determinate.

**Voussoir Arch.** A hingeless arch with both supports fixed against rotation. Originally built of wedge-shaped stone blocks or voussoirs, the hingeless arch may also be built of concrete.

**Arch Barrel.** An arch ring that extends the width of the structure.

**Arch Rib.** An arch ring unit used in unfilled and open spandrel arch construction in reinforced concrete. Two or more relatively narrow arch ring units or sections support the columns of the bays or panels. The construction may involve a combination of arch ribs with spandrel walls providing an outward appearance akin to that of an unfilled spandrel arch.

One of the arched girders of a plate girder rib arch.

**Arm.** 1. The portion of a swing bridge or of a retractile draw bridge which forms the span or a portion of the span of the structure. 2. The rear or counterweight leaf of a bascule span. 3. The overhanging (or cantilever) portion of a cantilever bridge which supports the suspended span. 4. In statics, the perpendicular distance between the two parallel equal and opposite forces of a moment.

**Armor.** A secondary steel member installed to protect a vulnerable part of another member, e.g., steel angles placed over the edges of a joint.

**Axle Load.** The load borne by one axle of a traffic vehicle, a movable bridge, or other motive equipment or device and transmitted through a wheel or wheels to a supporting structure.

## B

**Back.** See EXTRADOS.

**Backfill.** Material placed adjacent to an abutment, pier, retaining wall or other structure or part of a structure to fill the unoccupied portion of the foundation excavation.

Soil, usually granular, placed behind and within the abutment and wingwalls.

**Backstay.** The portion of the main suspension member of a suspension bridge extending between the tower and the anchorage. When this member continues over the towers from anchorage to anchorage, it does not support any portion of the bridge floor system which may be located between the tower and anchorage members of the structure.

A cable or chain attached at the top of a tower and extending to and secured upon the anchorage to resist overturning stresses exerted upon the tower by the suspension span attached to and located between towers.

**Backwall.** The topmost portion of an abutment above the elevation of the bridge seat, functioning primarily as a retaining wall with a live load surcharge. It may serve also as a support for the extreme end of the bridge deck and the approach slab.

**Backwater.** The water of a stream retained at an elevation above its normal level through the controlling effect of a condition existing at a downstream location such as a flood, an ice jam or other obstruction.

The increase in the elevation of the water surface above normal produced primarily by the stream width contraction beneath a bridge. The wave-like effect is most pronounced at and immediately upstream from an abutment or pier but extends downstream to a location beyond the body of the substructure part.

**Balance Blocks.** Blocks of cast iron, stone, concrete or other heavy weight material used to adjust the counterbalance of swing and lift spans.

**Balance Wheel.** (*Trailing Wheel.*) One of the wheels attached to the superstructure, normally having only a trailing contact upon a circular track surrounding the pivot of a center bearing swing bridge. These wheels maintain the proper balance and lateral stability of the superstructure by preventing excessive rocking or other motion due to wind pressures, shock from operating irregularities, or other causes. When correctly adjusted, a balance wheel will transmit only its own weight to the track and will revolve without load upon its axle.

**Balancing Chain.** See COUNTERBALANCING CHAIN.

**Ballast.** Filler material, usually broken stone or masonry, used either to stabilize a structure (as in filling a crib) or to transmit a vertical load to a lower level (as with a railroad track ballast).

**Baluster.** One of the column-like pieces composing the intermediate portion of a balustrade. Balusters may be varied in cross-sectional shape from round to square. See BALUSTRADE.

**Balustrade.** A railing composed of brick, stone or reinforced concrete located upon the retaining wall portion of an approach cut, embankment or causeway or at the outermost edge of the roadway or the sidewalk portion of a bridge to serve as a protection to vehicular and/or pedestrian traffic. Its major elements are: (1) plinth, (2) balusters, and (3) capping. However, the web portion may be built without openings instead of balustered or other open construction. See PARAPET.

**Base Metal, Structure Metal, Parent Metal.** The metal at and closely adjacent to the surface to be incorporated in a welded joint which will be fused, and by coalescence and interdiffusion with the weld will produce a welded joint.

**Base Plate.** A plate-shaped piece of steel, whether cast, rolled or forged, riveted upon or by other means made an integral part of the base portion of a column, pedestal or other member to transmit and distribute its load either directly or otherwise to the substructure or to another member.

**Batten Plate.** 1. A plate used to cover the joint formed by two abutting metal plates or shapes but ordinarily not considered as serving to transmit stress from one to the other. 2. A plate used in lieu of lacing to tie together the shapes comprising a built-up member. 3. A term sometimes used as synonymous with Stay Plates to indicate a plate in which the bar latticing or lacing of a bolted, riveted, or welded member terminates.

**Batter.** The inclination of a surface in relation to a horizontal or a vertical plane or occasionally in relation to an inclined plane. Batter is commonly designated upon bridge detail plans as so many inches to one foot. See RAKE.

**Batter Pile.** A pile driven in an inclined position to resist forces which act in other than a vertical direction. It may be computed to withstand these forces or, instead, may be used as a subsidiary part or portion of a structure to improve its general rigidity.

When driven and made fast upon the end of a pile bent or a piled pier located in a stream, river, or other waterway, it functions as a cutwater in dividing and deflecting floating ice and debris.

**Bay.** As applied to a stringer of multibeam structure, the area between adjacent stringers.

**Bead.** (*Run.*) A narrow continuous deposit of weld metal laid down in a single pass of fused filler metal.

**Beam.** 1. A simple or compound piece receiving and transmitting transverse or oblique stresses produced by externally applied loads, when supported at its end or at intermediate points and ends. The beam derives its strength from the development of internal bending or flexural stresses. 2. A rolled metal I-shaped or H-shaped piece. 3. An I-shaped piece or member composed of plates and angles or other structural shapes united by bolting, riveting or welding. In general, such pieces or members are described as built-up beams. These terms are applied to and define, in general terms only, variations in shape, size and arrangement of beam type members of reinforced concrete structures.

**Reinforced Concrete Beam.** Reinforced concrete beam is a construction wherein the tensile stresses, whether resulting from bending, shear, or combinations thereof produced by transverse loading, 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.

**Reinforced Concrete T-Beam.** Reinforced concrete T-beam derives its name from a similarity of shape to the letter "T," the head or topmost element of the letter consisting of a portion of the deck slab which is constructed integrally with the R/C beam stem.

**Bearing Failure.** Concerning the usual materials of construction, a crushing under extreme compressive load on an inadequate support; concerning soil, a shear failure in the supporting soil caused by excessively high pressures applied by a footing or pile.

**Bearing.** (*Fixed.*) A bearing which does not allow longitudinal movement.

**Bearing Pad.** A thin sheet of material placed between a masonry plate and the masonry bearing surface used to fill any voids due to imperfection of the masonry plate and bearing surface, to seal the interface, and to aid in even distribution of loads at the interface. The bearing pads may be made of alternating layers of red lead and canvas, of sheet lead, or of preformed fabric pads.

**Bearing Seat.** Top of masonry supporting bridge bearing.

**Bearings.** (*Live Load, Front Load, Outer.*) Live load bearings are a class of special bearings or supports installed on movable swing and bascule spans. These are engaged when the bridge is in the closed position taking the load off the trunnions and center pivot and preventing the outer end of the lift span from hammering on the rest pier under live load. Front load bearings are live load bearings placed on the support pier of a bascule bridge, and outer bearings are those on swing span and bascule rest piers.

**Bed Rock.** (*Ledge Rock.*) A natural mass formation of igneous, sedimentary, or metamorphic rock material either outcropping upon the surface, uncovered in a foundation excavation, or underlying an accumulation of unconsolidated earth material.

**Bench Mark.** A point of known elevation.

**Bent.** A supporting unit of a trestle or a viaduct type structure made up of two or more column or column-like members connected at their topmost ends by a cap, strut, or other member holding them in their correct positions. This connecting member is commonly designed to distribute the superimposed loads upon the bent, and when combined with a system of diagonal and horizontal bracing attached to the columns, the entire construction functions somewhat like a truss distributing its loads into the foundation.

When piles are used as the column elements, the entire construction is designated a "pile bent" or "piled bent" and, correspondingly, when those elements are framed, the assemblage is termed a "frame bent."

**Berm.** (*Berme.*) The line, whether straight or curved, which defines the location where the top surface of an approach embankment or causeway is intersected by the surface of the side slope. This term is synonymous with "Roadway Berm."

A horizontal bench located at the toe of slope of an approach cut, embankment or causeway to strengthen and secure its underlaying material against sliding or other displacement into an adjacent ditch, borrow pit, or other artificial or natural lower lying area.

**Blanket.** A protection against stream scour placed adjacent to abutments and piers and covering the stream bed for a distance from these structures considered adequate for the stream flow and stream bed conditions. The stream bed covering commonly consists of a deposit of stones of varying sizes which, in combination, will resist the scour forces. A second type consists of a timber framework so constructed that it can be ballasted and protected from displacement by being loaded with stones or with pieces of wrecked concrete structures or other adaptable ballasting material.

**Bcster.** A block-like member composed of wood, metal, or concrete used to support a bearing on top of a pier cap or abutment bridge seat. It may adjust bearing heights and avoid constructing the bridge seat to the crown of the roadway, provide an area that may be ground to a precise elevation, or raise a bearing above moisture and debris that may collect on the bridge seat. See also BRIDGE PAD and BRIDGE SEAT PEDESTAL.

**Bolted Joint.** See RIVETED JOINT.

**Bond.** 1. In reinforced concrete, the grip of the concrete on the reinforcing bars, thereby preventing slippage of the bars. 2. The mechanical bond resulting from irregularities of surface produced in the manufacturing operations is an important factor in the strength of a reinforced concrete member. For plain round bar reinforcement, it is the difference between the force required to produce initial slip and the ultimate, producing failure. "Deformed" bars utilize this mechanical bond in conjunction with the surface bond. 3. The mechanical force developed between two concrete masses when one is cast against the already hardened surface of the other.

**Bond Stress.** A term commonly applied in reinforced concrete construction to the stress developed by the force tending to produce movement or slippage at the interface between the concrete and the metal reinforcement bars or other shapes.

**Bowstring Truss.** A general term applied to a truss of any type having a polygonal arrangement of its top chord members conforming to or nearly conforming to the arrangement required for a parabolic truss.

A truss having a top chord conforming to the arc of a circle or an ellipse. See PARABOLIC TRUSS.

**Box Beam.** A rectangular-shaped precast, and usually prestressed, concrete beam. These beams may be placed side by side, connected laterally, and used to form a bridge deck, with or without a cast-in-place slab or topping. In such cases, the beam units act together similar to a slab. Where a C-I-P slab is used and the units are spread, they act as beams.

**Box Girder (concrete).** A large concrete box-shaped beam, either reinforced or prestressed, usually multi-celled with several interior webs. The bottom slab of the girder serves as a flange only, while the top slab is both a flange and a transverse deck slab.

**Box Girder (steel).** A steel beam or girder, with a rectangular or trapezoidal cross section, composed of plates and angles or other structural shapes united by bolting, riveting, or welding, and having no interior construction except stiffeners, diaphragms, or other secondary bracing parts.

Recently, large steel multi-cell boxes with interior webs have been used as have composite steel box girders in which the concrete slab forms the top side of the box.

**Bracing.** A system of tension or of compression members, or a combination of these, forming with the part or parts to be supported or strengthened a truss or frame. It transfers wind, dynamic, impact, and vibratory stresses to the substructure and gives rigidity throughout the complete assemblage. In general, the bracing of a girder or of a truss span employs:

(1) A system of horizontal bracing in the planes of the top and bottom flanges or chords, designated according to its location, the top flange, top chord, top or overhead lateral brac-

ing, and the bottom flange, bottom chord or lower lateral bracing.

(2) Cross or X-bracing when placed transversely in vertical planes between beams and stringers and having diagonal members crossed, sometimes termed "Cross Frame." It functions as a diaphragm.

(3) Sway or buck bracing when placed transversely in vertical or nearly vertical planes between trusses. The term "overhead bracing," when applied here, is more appropriate than when applied to the top chord lateral bracing.

(4) Portal bracing consisting of a system of struts, ties and braces placed in the plane of the end posts of the trusses. Portal bracing may be in the plane of one flange of the end posts and described as a "single plane" portal or it may engage both flanges and be described as a "box portal." Without regard to its shape or details the entire portal bracing member is frequently designated as a "portal."

In general, the bracing of trestle and viaduct bents and towers employs:

(1) Transverse bracing engaging the columns of bents and towers in planes located either perpendicular or slightly inclined and transversely to the bridge alignment.

(2) Longitudinal bracing engaging the columns of bents and towers in planes located either perpendicular or slightly inclined and lengthwise with the bridge alignment.

(3) Horizontal bracing engaging the strut members of the transverse and longitudinal bracing of towers. Commonly this bracing is located in a horizontal position and is supported against sagging by vertical hangers or ties.

**Bracket.** A projecting support or brace-like construction fixed upon two intersecting members to function: (1) as a means of transferring reactions or shear stress from one to the other, or (2) to strengthen and render more rigid a joint connection of the members, or (3) to simply hold one member in a fixed position with relation to the other.

**Breast Wall.** (*Face Wall, Stem.*) The portion of an abutment between the wings and beneath the bridge seat. The breast wall supports the superstructure loads, and retains the approach fill.

**Brick Veneer.** See STONE FACING.

**Bridge.** A structure providing a means of transit for pedestrians and/or vehicles above the land and/or water surface of a valley, arroyo, gorge, river, stream, lake, canal, tidal inlet, gut or strait; above a road, highway, railway or other obstruction, whether natural or artificial.

In general, the essential parts of a bridge are: (1) the substructure consisting of its abutments and pier or piers supporting the superstructure, (2) the superstructure slab, girder, truss, arch or other span or spans supporting the roadway loads and transferring them to the substructure, and (3) the roadway and its incidental parts functioning to receive and transmit traffic loads.

**Bridge (composite).** A bridge whose concrete deck acts structurally with longitudinal main carrying members.

**Bridge (indeterminate).** A structure in which forces in the members cannot be determined by static equations alone.

**Bridge (prestressed).** A bridge whose main carrying members are made of prestressed concrete.

**Bridge Pad.** The raised, levelled area upon which the pedestal, shoe, sole, plate or other corresponding element of the superstructure takes bearing by contact. Also called Bridge Seat Bearing Area.

**Bridge Seat.** The top surface of an abutment or pier upon which the superstructure span is placed and supported. For an abutment it is the surface forming the support for the superstructure and from which the backwall rises. For a pier it is the entire top surface.

**Bridge Site.** The selected position or location of a bridge.

**Bridging.** A carpentry term applied to the cross-bracing, nailed or otherwise, fastened between wooden floor stringers, usually at the one-third span points, to increase the rigidity of the floor construction and to distribute more uniformly the live load and minimize the effects of impact and vibration.

**Brush Curb.** A narrow curb, 9 inches or less in width, which prevents a vehicle from brushing against the railing or parapet.

**Buckle.** To fail by an inelastic change in alignment (usually as a result of compression).

**Buffer.** (*Bumper.*) A mechanism designed to absorb the concussion or impact of a moving superstructure or other moving part when it swings, rises or falls to its limiting position of motion.

**Built-Up Column.** (*Built-Up Girder.*) A column, beam or girder, as the case may be, composed of plates and angles or other structural shapes united by bolting, riveting or welding to render the entire assemblage a unit. A built-up girder is commonly described as a plate girder.

**Bulkhead.** 1. A retaining wall-like structure commonly composed of driven piles supporting a wall or a barrier of wooden timbers or reinforced concrete members functioning as a constraining structure resisting the thrust of earth or of other material bearing against the assemblage. 2. A retaining wall-like structure composed of timber, steel, or reinforced concrete members commonly assembled to form a barrier held in a vertical or an inclined position by members interlocking therewith and extending into the restrained material to obtain the anchorage necessary to prevent both sliding and overturning of the entire assemblage.

**Bumper.** See BUFFER.

**Buttress.** A bracket-like wall, of full or partial height, projecting from another wall. The buttress strengthens and stiffens the wall against overturning forces applied to the opposite face by virtue of its depth in the direction of the loads. A buttress may be either integral with or independent of, but must be in contact with, the wall it is designed to reinforce. All parts of a buttress act in compression.

**Buttressed Wall.** See RETAINING WALL.

**Butt Weld.** A weld joining two abutting surfaces by depositing weld metal within an intervening space. This weld serves to unit the abutting surfaces of the elements of a member or to join members or their elements abutting upon or against each other.

## C

**Cable.** One of the main suspension members of a suspension type bridge. Its function is to receive the bridge floor loads and transmit them to the towers and anchorages. See SUSPENSION BRIDGE.

**Cable Band.** The attachment device serving to fix a floor suspender upon the cable of a suspension bridge. In general this device consists of a steel casting provided with bolts or other appliances to securely seize it upon the cable and prevent the bank from slipping from its correct location.

**Camber.** The slightly arched form or convex curvature, provided in a single span or in a multiple span structure, to compensate for dead load deflection and to secure a more substantial and aesthetic appearance than is obtained when uniformly straight lines are produced. In general, a structure built with perfectly straight lines appears slightly sagged. This optical illusion is unsatisfactory and is most manifest in relatively long structures over rivers or other water areas.

The superelevation given to the extreme ends of a swing span during erection to diminish the deflection or "droop" of the arms when in open position-cantilevered from the center bearing. The decreased deformation below the normal position reduces the energy required to raise the ends in the closed position to permit the arms to function as simple spans.

**Cantilever.** A projecting beam, truss, or slab supported at one end only.

**Cantilever Abutment.** See ABUTMENT.

**Cantilever Bridge.** A general term applying to a bridge having a superstructure of the cantilever type.

**Cantilever Beam, Girder, or Truss.** A girder or truss having its members or parts so arranged that one or both of its end portions extend beyond the point or points of support. In general, it may have the following forms: (1) two projecting ends counterbalanced over a center support; (2) a projecting end counterbalanced in part by a portion extending beyond the point of support in the opposite direction, and having at its end an uplift resisting anchorage to complete the condition of equilibrium or, instead, the counterbalancing portion or anchor arm may in itself be adequate to counteract the projecting portion; (3) two projecting ends with an intermediate suspended portion, whose weight is completely counterbalanced by the anchor spans and/or anchorages. The end portions may or may not be alike in design.

**Cantilever Span.** A superstructure span of a cantilever bridge composed of two cantilever arms or of a suspended span connected with one or two cantilever arms.

**Cap.** (*Cap Beam, Cap Piece.*) The topmost piece or member of a viaduct, trestle, or frame bent serving to distribute the loads upon the columns and to hold them in their proper relative positions.

The topmost piece or member of a pile bent in a viaduct or trestle serving to distribute the loads upon the piles and to hold them in their proper relative positions. See PIER CAP and PILE CAP.

**Capillary Action.** The process by which water is drawn from a wet area to a dry area through the pores of a material.

**Capstone.** 1. The topmost stone of a masonry pillar, column or other structure requiring the use of a single capping element. 2. One of the stones used in the construction of a stone parapet to make up its topmost or "weather" course. Commonly this course projects on both the inside and outside beyond the general surface of the courses below it.

**Carnegie Beam.** See WIDE FLANGE.

**Catch Basin.** A receptacle, commonly box-shaped and fitted with a grilled inlet and a pipe outlet drain designed to collect the rain water and floating debris from the roadway surface and retain the solid material so that it may be removed at intervals. Catch basins are usually installed beneath the bridge floor or within the approach roadway with the grilled inlet adjacent to the roadway curb.

**Catchment Area.** See DRAINAGE AREA.

**Catwalk.** A narrow walkway for access to some part of a structure.

**Cement Paste.** The plastic combination of cement and water that supplies the cementing action in concrete.

**Cement Matrix.** The binding medium in a mortar or concrete produced by the hardening of the cement content of the mortar, concrete mixture of inert aggregates, or hydraulic cement and water.

**Center Bearing.** The complete assemblage of pedestal castings, pivot, discs, etc., functioning to support the entire dead load of a swing span when the end lifts are released or the span is revolving to "open" or to "closed position."

**Center Discs.** The assemblage of bronze, steel or other metal discs enclosed in the pivot of a center bearing swing span to reduce the frictional resistance in the operation of the span.

**Center Lock.** A locking device that transmits shear at the centerline of a double leaf bascule or double swing span bridge. This eliminates deflection and vibration at the center of the span.

**Center Wedges.** On a swing bridge, the assembly of pedestals and wedges located upon the pivot pier beneath the loading girder and operated mechanically to receive the pivot pier live loads and transmit them direct to the substructure, thus relieving the pivot casting from all, or nearly all, live load stress.

**Centering.** The supporting structure upon which the arch ring is constructed. This commonly consists of timber or metal framework having its topmost portion shaped to conform with the arch intrados and finished by covering with lagging or with bolsters, the latter being spaced to permit treatment of the mortared joints of stone masonry.

Support for formwork for any slab, beam, or other generally horizontal concrete structure.

**Centering Device.** The mechanical arrangement or device which guides the span of a bascule or a vertical lift span to its correct location upon its supports when being moved from open to closed position.

**Channel Profile.** Longitudinal section of a channel.

**Chase.** A channel, groove or elongated recess built into a structure surface for 1) the reception of a part forming a joint or (2) the installation of a member or part of the structure.

**Check Analysis.** See LADLE ANALYSIS.

**Chord.** In a truss, the upper and the lower longitudinal members, extending the full length and carrying the tensile and compressive forces which form the internal resisting moment, are termed chords. The upper portion is designated the upper, or top, chord and correspondingly the lower portion is designated the lower, or bottom, chord. The chords may be paralleled, or the upper one may be polygonal or curved (arched) and the lower one horizontal, or both may be polygonal. In general, the panel points of polygonal top chords are designed to follow the arc of a parabola and are, therefore, truly parabolic chords. Polygonal shaped chords are commonly described as "broken chords."

**Chord Members.** Trusses are commonly divided lengthwise into panels, the length of each being termed a panel length. The corresponding members of the chords are described as upper, or top, chord members and lower, or bottom, chord members.

**Clearance.** The unobstructed space provided: (1) in a through or half-through truss or a through plate girder type bridge, and (2) upon a deck truss or girder type bridge for the free passage of vehicular and pedestrian traffic. Clearance is measured in vertical and horizontal (lateral) dimensions and may or may not be determined or regulated by standard (clearance diagram) requirements. Vertical clearance for vehicles is measured above the elevation of the floor surface at its crown dimension while horizontal clearance is commonly measured from or with reference to the edge of travelway.

The unobstructed space provided below a bridge superstructure for (1) the passage of a river or stream with its surface burden of floating debris; (2) the passage of navigation craft commonly designated "clear headway" and (3) the passage of vehicular and pedestrian traffic. This form of clearance is frequently designated "under-clearance" to differentiate it from the provision for the requirements of the transportation service supported by the structure.

The space allowed for (1) the tolerance permitted in the dimensions of structural shapes; (2) the free assembling and adjustment of the elements of members or the members of a structure; and (3) the variations in dimensions incident to workmanship, temperature changes and minor irregularities. Among shop and field workers this condition is sometimes described as "the go and come" or "the play" allowance.

**Clear Headway.** (*Headway.*) The vertical clearance beneath a bridge structure available for the use of navigation. See CLEARANCE. In tidal waters headway is measured above mean high tide elevation.

**Clear Span.** The unobstructed space or distance between the substructure elements measured, by common practice, between faces of abutments and/or piers. However, when a structure is located upon a stream, river, tidal inlet or other waterway used by navigation, the clear span dimension is measured at mean low water elevation and may be the distance between guard or fender piers, dolphins or other constructions for the protection of navigation.

**Clevis.** A forked device used to connect the end of a rod upon a gusset plate or other structural part by means of a pin. It commonly consists of a forging having a forked end arranged to form two eyes or eyelets for engaging a pin and a nut-like portion, constructed integrally therewith, for engaging the correspondingly threaded end of a rod. However, the forked end (clevis) may form an integral portion of a rod without provision for adjustment of its length. An adjustable member having a fixed clevis at one end may be fitted with a thread and nut at its opposite end while one having fixed clevises at its ends may be fitted with either a sleeve nut or a turnbuckle in its midlength portion. Lateral bracing and tie-rod diagonals on old steel trusses often use clevises.

**Clevis Bar.** A member consisting of a rod having upset threaded ends fitted with clevises for engaging end connection pins. To render a clevis bar adjustable after assembling in a structure its ends are right and left threaded, or it may be constructed with a sleeve nut or a turnbuckle within its length, the end threads upon each of its sections being right and left hand and its clevises forged integrally with the body sections of the bar.

**Clip Angle.** See CONNECTION ANGLE.

**Coefficient of Thermal Expansion.** The unit strain produced in a material by a change of one degree in temperature.

**Cofferdam.** In general, an open box-like structure constructed to surround the area to be occupied by an abutment, pier, retaining wall or other structure and permit unwatering of the enclosure so that the excavation for the preparation of a foundation and the abutment, pier, or other construction may be effected in the open air. In its simplest form, the dam consists of interlocking steel sheet piles. See SHEET PILE COFFERDAM.

**Collision Strut.** A redundant member intended to reinforce the inclined end post of a through truss against damage from vehicular traffic. It joins the end post at a height above the roadway conceived to be the location of collision contact and, commonly, connects it with the first interior bottom chord panel point. The use of collision struts in highway bridges is limited.

**Cold Work.** The forming, such as rolling or bending, of a material at ordinary room temperature. Also applied to such deformation of steel elements in service under concentrated forces.

**Column.** A general term applying to a member resisting compressive stresses and having, in general, a considerable length in comparison with its transverse dimensions. This term is sometimes used synonymously for "post."

A member loaded primarily in compression. See also STRUT, POST, PILLAR.

**Composite Joint.** A joint in which the strength, rigidity or other requisites of its function are developed by combined mechanical devices, or by a fusion weld in conjunction with one or more mechanical means or appliances. The uncertain functioning of joints of this type makes their use undesirable.

**Compound Roller.** A roller consisting of a large solid cylinder at the center surrounded by a nest of smaller solid rollers having circular spacing bars engaging their ends and enveloped in a large hollow cylinder which forms the exterior surface of the assemblage. The large roller is commonly bored throughout its length at its center to permit observation of its interior material.

**Compression (inelastic).** Compression beyond the yield point.

**Concrete.** A composite material consisting essentially of a binding medium within which are embedded particles or fragments of a relatively inert mineral filler. In portland cement concrete, the binder or matrix, either in the plastic or the hardened state, is a combination of portland cement and water. The filler material, called aggregate, is generally graded in size from fine sand to pebbles or stones which may, in some concrete, be several inches in diameter.

Concrete is used in conjunction with stone fragments or boulders, of "one man" size or larger, imbedded therein to produce "cyclopean" or "rubble" concrete.

**Connection Angle.** (*Clip Angle.*) A piece or pieces of angle serving to connect two elements of a member or two members of a structure.

**Consolidation.** The time-dependent change in volume of a soil mass under compressive load caused by pore-water slowly escaping from the pores or voids of the soil. The soil skeleton is unable to support the load by itself and changes structure, reducing its volume and usually producing vertical settlements.

**Continuous Girder.** A general term applied to a beam or girder constructed continuously over one or more intermediate supports.

**Continuous Spans.** A beam, girder, or truss type superstructure designed to extend continuously over one or more intermediate supports.

**Continuous Truss.** A truss having its chord and web members arranged to continue uninterruptedly over one or more intermediate points of support, i.e., having three or more points of support.

**Continuous Weld.** A weld extending throughout the entire length of a joint.

**Coping.** A course of stone laid with a projection beyond the general surface of the masonry below it and forming the topmost portion of a retaining wall, pier, abutment, wingwall, etc. In general, the top surface is battered (washed) to prevent accumulation of rain or other moisture thereon.

A course of stone capping the curved or V-shaped extremity of a pier, providing a transition to the pier head proper. When so used it is commonly termed the "starling coping," "nose coping," the "cut-water coping" or the "pier extension coping."

In concrete construction the above terms are used without change.

**Corbel.** A piece or part constructed to project from the surface of a wall, column or other portion of a structure to serve as a support for a brace, short, beam or other member.

A projecting course or portion of masonry serving: (1) as a support for a superimposed member or members of a structure, or (2) as a part of the architectural treatment of a structure. In stone and brick masonry construction, this form of corbel is termed a "corbel course" implying greater length than that of a simple corbel.

**Corrosion.** The general disintegration and wasting of surface metal or other material through oxidation, decomposition, temperature, and other natural agencies.

**Corrosion (electrolytic).** Corrosion resulting from galvanic action.

**Cotter Bolt.** A bolt having a head at one end and near the opposite end a round hole or a hexagonal slot fitted with a cotter pin in the former or a tapered wedge in the latter. A cotter pin is usually formed by bending a piece of half-round rod to form a loop eye and a split body permitting its end to be splayed, thus holding it in position while a cotter wedge may be split for the same purpose, but either of these locking devices may be undivided and only bent sharply to prevent withdrawal. Cotter bolts are commonly fitted with one or two washers.

A cotter bolt fitted with a key is sometimes termed a "key bolt."

**Counter.** A truss web member which functions only when the span is partially loaded and shear stresses are opposite in sign to the normal conditions. The dead load of the truss does not stress the counter. See WEB MEMBERS.

**Counterbalancing Chain.** (*Balancing Chain.*) The chains made a part of the operating equipment of a vertical lift bridge to function as a weight counteracting the varying weight of the supporting cables incidental to the movements of the span.

**Counterfort.** A bracket-like wall projecting from another wall to which it adds stability by being integrally built with or otherwise securely attached to the side to which external forces are applied tending to overturn it. A counterfort, as opposed to a buttress, acts entirely to resist tensile and bending stresses. It may extend from the base either part or all the way to the top of the wall it is designed to reinforce.

**Counterforted Wall.** See RETAINING WALL.

**Counterweight.** A weight placed in position so as to counter balance the weight of a movable part (such as bascule leaf or vertical lift span).

**Counterweight Well.** (*Tail Pit.*) The enclosed space located beneath the bridge floor at the approach end to accommodate the counterweight and its supporting frame during the opening-closing cycle of the movable span of certain types of bascule bridge structures.

**Course.** In stone masonry, a layer of stone composed of either cut or uncut pieces laid with horizontal or slightly longitudinally inclined joints.

In brick masonry, a layer of bricks bedded in mortar.

**Cover.** In reinforced concrete, the clear thickness of concrete between a reinforcing bar and the surface of the concrete.

**Cover Plate.** A plate used in conjunction with flange angles or other structural shapes to provide additional flange section upon a girder, column, strut or similar member.

**Covered Bridge.** An indefinite term applied to a wooden bridge having in its construction a truss of any type adaptable to its location requirements. To prevent or delay deterioration of the timbers through infiltration of moisture into the framed or other joints, the entire structure, or instead, only its trusses are covered by a housing consisting of boards and shingles or other covering materials, fastened upon the side girts, rafters, purlins, or other parts intended to receive them. A covered bridge may be either a through or a deck structure. The former may be constructed with pony trusses.

**Cracking (reflection).** Visible cracks in an overlay indicating cracks in the concrete underneath.

**Creep.** An inelastic deformation that increases with time while the stress is constant.

**Crib.** A structure consisting of a foundation grillage combined with a superimposed framework providing compartments or coffers which are filled with gravel, stones, concrete or other material satisfactory for supporting the masonry or other structure to be placed thereon. The exterior portion may be planked or sheet-piled to protect the crib against damage by erosion or floating debris.

A structure consisting of a series of box-like compartments built of round or squared timbers having the crosstimbers (compartment division and end wall timbers) drift bolted and dove-tail framed or half framed to interlock with the side timbers, thus producing a rigid framework of the height desired. A portion of the compartment is constructed with floors to serve as ballast boxes for loading and sinking the crib in its final position after which the remaining compartments are filled or partially filled with gravel, stones or other material to render the entire structure stable against the forces to which it may be subjected.

This latter type of crib is used as a protection against wave action and stream currents producing scour and erosion adjacent to bridge structures to prevent undermining of abutments and piers or other substructure elements and also to serve as a training wall averting changes in shore and bank locations.

**Cribbing.** A construction consisting of wooden, metal or reinforced concrete units so assembled as to form an open cellular-like structure for supporting a superimposed load or for resisting horizontal or overturning forces acting against it.

**Cross Frames.** Transverse bracings between two main longitudinal members. See DIAPHRAGM and BRACING.

**Cross Girder, Transverse Girder.** A term applied to large timber members and to metal and reinforced concrete girder-like members placed generally perpendicular to and connected upon the main girders or trusses of a bridge span, including intermediate and end floor beams.

**Cross Wall.** See DIAPHRAGM WALL.

**Crown of Roadway.** 1. The crest line of the convexed surface. 2. The vertical dimension describing the total amount the surface is convexed or raised from gutter to crest. This is sometimes termed the cross fall of roadway.

**Culvert.** A small bridge constructed entirely below the elevation of the roadway surface and having no part or portion integral therewith. Structures over 20 feet in span parallel to the roadway are usually called bridges, rather than culverts; and structures less than 20 feet in span are called culverts even though they support traffic loads directly.

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

**Curb Inlet.** See SCUPPER.

**Curtain Wall.** A term commonly applied to a thin masonry wall not designed to support superimposed loads either vertically or transversely.

A thin vertically placed and integrally built portion of the paving slab of a culvert intended to protect the culvert against undermining by stream scour. A similar construction placed in an inclined position is termed an "apron wall" or "apron."

A wall uniting the pillar or shaft portions of a dumbbell pier. However, its service function is that of a frame composed of struts and braces rendering the entire structure integral in its action. As here applied the term is synonymous with "diaphragm wall."

**Curve Banking.** See SUPERELEVATION.

**Curves in Plan and Profile.** A roadway may be curved in its lateral alignment, its vertical contour, or in both alignment and contour combined. The primary curves are described as:

1. Horizontal Curve. A curve in the plan location defining the alignment.

2. Vertical Curve. A curve in the profile location defining the elevation.

Cut. (*Cutting.*) That portion of a highway, railway, canal, ditch or other artificial construction of similar character produced by the removal of the natural formation of earth or rock whether sloped or level. The general terms "side hill cut" and "through cut" are used to describe the resulting cross sections of the excavations commonly encountered.

**Cut Slope.** A term applied to the inclined surface of an approach cut terminating in the ditch or gutter at its base, which in turn serves to remove accumulations of water from all areas drained into it.

**Cylinder Pier.** See PIER.

D

**Dead Load.** A static load due to the weight of the structure itself.

**Dead Man.** A general term applied to an anchorage member engaging the end of a stay rod, cable or other tie-like piece or part. The anchorage member is made secure through the resistance to movement produced by the earth, stone, brickbats, or other material used to embed and cover the anchor piece which may consist of a wooden log or timber, a metal beam or other structural shape, a quarried stone boulder or any other adaptable object. This type of anchor member is used to restrain and hold in position piles, bulkheads, cribs, and other constructions against horizontal movement as well as to resist the stresses of tie members acting in inclined and vertical directions.

**Debris Rack.** A grill type barrier used to intercept debris above a sewer or culvert inlet.

**Deck.** That portion of a bridge which provides direct support for vehicular and pedestrian traffic. The deck may be either a reinforced concrete slab, timber flooring, a steel plate or grating, or 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 timber bridge.

**Deck Bridge.** A bridge having its floor elevation at, nearly at, or above the elevation of the uppermost portion of the superstructure.

**Decking.** A term specifically applied to bridges having wooden floors and used to designate the flooring only. It does not include the floor stringers, floor beams, or other members serving to support the flooring.

**Deformation (elastic).** Deformation occurring when stress in a material is less than the yield point. If the stress is removed, the material will return to its original shape.

**Depth of Truss.** As applied to trusses having parallel chords and to polygonal trusses having a midspan length with parallel chords; the vertical distance between the centerlines of action of the top and bottom chords.

**Design Load.** The loading comprising magnitudes and distributions of wheel, axle or other concentrations used in the determination of the stresses, stress distributions and ultimately the cross-sectional areas and compositions of the various portions of a bridge structure.

The design loading or loadings fixed by a specification are very commonly composite rather than actual, but are predicated upon a study of various types of vehicles. In lieu of a loading so determined for use as "standard," an equivalent uniform load designed to produce resulting structures practically identical with those evolved by the use of such loadings may be used. One or more concentrated loads may be used in conjunction with the uniform load to secure the effect corresponding to the incorporation of especially heavy vehicles within the normally maximum traffic considered as likely to pass upon a given bridge or a series of bridges. Such equivalent loadings are merely a convenience facilitating design operations.

In rating bridges for the Bridge Inspection Manual, either the H or HS trucks with their alternate lane loadings may be used. Or, if desired, the special legal limit trucks: Type 3, Type 3S 2, and Type 3–3, may be used.

**Diagonal.** See WEB MEMBERS.

**Diagonal Stay.** A cable support in a suspension bridge extending diagonally from the tower to the roadway system to add stiffness to the structure and diminish the deformations and undulations resulting from traffic service.

**Diaphragm.** A reinforcing plate or member placed within a member or deck system, respectively, to distribute stresses and improve strength and rigidity. See BRACING.

**Diaphragm Wall (cross wall).** A wall built transversely to the longitudinal centerline of a spandrel arch serving to tie together and reinforce the spandrel walls together with providing a support for the floor system in conjunction with the spandrel walls. To provide means for the making of inspections the diaphragms of an arch span may be provided with manholes.

The division walls of a reinforced concrete caisson dividing its interior space into compartments and reinforcing its walls. A wall serving to subdivide a box-like structure or portion of a structure into two or more compartments, or sections.

**Dike.** (*Dyke*). An earthen embankment constructed to provide a barrier to the inundation of an adjacent area which it encloses entirely or in part.

When used in conjunction with a bridge, its functions are commonly those of preventing stream erosion and localized scour and/or to so direct the stream current that debris will not accumulate upon bottom land adjacent to approach embankments, abutments, piers, towers, or other portions of the structure.

This term is occasionally misapplied to crib construction used to accomplish a like result. See CRIB.

**Spur Dike.** A projecting jetty-like construction placed adjacent to an abutment of the "U," "T," block or arched type upon the upstream and downstream sides, but sometimes only on the upstream side, to secure a gradual contraction of the stream width and induce a free even flow of water adjacent to and beneath a bridge. They may be constructed in extension of the wing wall or a winged abutment.

The common types of construction used for water wings are: (1) Wooden cribs filled with stones; (2) embankments riprapped on the waterway side; and (3) wooden and metal sheet piling.

Spur dikes serve to prevent stream scour and undermining of the abutment foundation and to relieve the condition which otherwise would tend to gather and hold accumulations of stream debris against and adjacent to the upstream side of the abutment.

**Dimension Stone.** A stone of relatively large dimensions, the face surface of which is either chisel or margin drafted but otherwise rough and irregular, commonly called either "rock face" or "quarry face."

Stones quarried with the dimensions large enough to provide cut stones with given finished dimensions.

**Distribution Girder.** A beam or girder-like member forming a part of the frame by which the dead and live loads are transmitted to the drum girder of a rim-boaring swing span.

**Ditch.** See DRAIN.

**Diversion Drain.** (*Diversion Flume.*) An open top paved drain constructed for the purpose of diverting and conveying water from a roadway gutter down the inclined surface of a bridge approach embankment or causeway.

**Dolphin.** A group or cluster of piles driven in one to two circles about a center pile and drawn together at their top ends around the center pile to form a buffer or guard for the protection of channel span piers or other portions of a bridge exposed to possible injury by collision with waterbound traffic. The tops of the piles are served with a wrapping consisting of several plies of wire, rope, coil, twist link, or stud link anchor chain, which, by being fastened at its ends only, renders itself taut by the adjustments of the piles resulting from service contact with ships, barges, or other craft. The center pile may project above the others to serve as a bollard for restraining and guiding the movements of water-borne traffic units.

Single steel and concrete piles of large size may also be used as dolphins.

**Double Movable Bridge.** A bridge in which the clear span for navigation is produced by joining the arms of two adjacent swing spans or the leaves of two adjacent bascule spans at or near the center of the navigable channel. The arms or leaves may act as cantilevers with a shear lock at their junction to provide for the passage of traffic over the joint. The leaves of bascules may be equipped to act as a hinged arch. Spans comprised of two bascule leaves are called double leaf bascule bridges. See MOVABLE BRIDGE.

**Dowel.** A short length of metal bar, either round or square, used to attach and prevent movement and displacement of wooden, stone, concrete, or metal pieces when placed in a bored, drilled, or cored hole located in their contact surfaces. A dowel may or may not be sized to provide a driving fit in the hole. In stone and premolded concrete structures the dowels are commonly set in lead, mortar, or other material filling the portions of the holes not occupied by the dowels. In concrete construction the plastic concrete is usually either placed around a dowel or the dowel is thrust into it.

In general, dowels function to resist shear forces, although footing dowels in reinforced concrete walls and columns resist bending forces.

**Drain.** (*Ditch, Gutter.*) A trench or trough-like excavation made to collect water. In general a drain is considered as functioning to collect and convey water whereas a ditch may only serve to collect it.

A gutter is a paved drain commonly constructed in conjunction with the curbs of the roadway or instead built closely adjacent to the paved portion of the roadway.

**Drain Hole.** (*Drip Hole.*) An aperture extending through a wall to provide an egress for water which might otherwise accumulate upon one of its sides. In this connection the term "weep hole" and "drain hole" are commonly used. See WEEP HOLE.

A cored, punched or bored hole in a box or trough shaped member or part to provide means for the egress of accumulated water or other liquid matter. In areas exposed to freezing temperatures, these holes are used to prevent damage by the expansive force incident to the freezing of water accumulations.

**Drainage.** The interception and removal of water from the roadway and/or sidewalk surfaces of a bridge or its approaches; from beneath the paved or otherwise prepared roadway and/or sidewalk surfaces of the approaches and from the sloped surfaces of hillsides, cuts, embankments, and causeways; from the backfill or other material in contact with abutments, retaining walls, counterweight wells or parts of a bridge or incidental structure.

A ditch, drain, gutter, gully, flume, catch basin, downspout, scupper, weep hole, or other construction or appliance facilitating the interception and removal of water.

**Drainage Area, Catchment Area.** The area from which the run-off water passing beneath a bridge or passing a specific location in a river or stream is produced.

**Drawbridge.** A general term applied to a bridge over a navigable stream, river, lake, canal, tidal inlet, gut or strait having a movable superstructure span of any type permitting the channel to be freed of its obstruction to navigation. A popular but imprecise term.

Probably the earliest use of a drawbridge was for military purposes, utilizing a single leaf hinged frame lifted up or let down by a comparatively simple manually operated mechanism.

**Draw Rest.** A support constructed upon a fender or guard pier and equipped with a latch block for holding a swing span in open position. This support may consist of a block of masonry, a rigid metal frame or other construction adapted to the service requirements.

**Draw Span.** A general term applied to either a swing or a retractile type movable superstructure span of a bridge over a navigable stream, river, lake, canal, tidal inlet, gut or strait. See MOVABLE BRIDGE.

**Drift Bolt.** A short length of metal bar, either round or square, used to connect and hold in position wooden members placed in contact. It may or may not be made with a head and a tapered point. Drift bolts are commonly driven in holes having a diameter slightly less than the bolts. This condition appears to be the recognized practical difference between a drift bolt and a dowel. The difference is more a matter of usage of terms rather than of functions to be performed.

**Drip Bead.** A channel or groove in the under side of a belt course, coping, or other protruding exposed portion of a masonry structure intended to arrest the downward flow of rain water and cause it to drip off free from contact with surfaces below the projection.

**Drip Hole.** See DRAIN HOLE.

**Drop Inlet.** A box-like construction commonly built integrally with the upstream end of a culvert with provision for the water to flow in at its top and to enter the culvert proper at its bottom or within its bottom portion. Vegetable or other material likely to become lodged in the culvert may be retained in the base portion of this receiving device by constructing its base to form a sump below the inlet elevation of the culvert. The culvert inlet may or may not be provided with a grating.

**Drum Girder.** (*Rim Girder.*) The circular plate girder forming a part of a swing bridge turntable transferring its loadings to the rollers and to the circular track upon which they travel. When the swing span is in "closed" position the drum girder track receives the superstructure dead and live loads and transmits these to the substructure bearing area beneath the track.

**Ductility.** The ability to withstand non-elastic deformation without rupture.

**Dyke.** See DIKE.

E

**Efflorescence.** A white deposit on concrete or brick caused by crystallization of soluble salts brought to the surface by moisture in the masonry.

**Elastic Deformation.** See DEFORMATION.

**Elastomer.** A natural or synthetic rubber-like material.

**Electrolytic Corrosion.** See CORROSION (ELECTROLYTIC).

**Element.** Metal Structures. An angle, beam, plate or other rolled, forged or cast piece of metal forming a part of a built piece. For Wooden Structures. A board, plank, joist, scantling or other fabricated piece forming a part of a built piece.

**End Block.** On a prestressed concrete beam, the thickening of the web or increase in beam width at the end to provide adequate anchorage bearing for the post-tensioning wires, rods, or strands.

**End Hammer.** The hammering action of an end lift device upon its pedestal or bearing plate resulting from the deflections and vibrations set up by the movements of traffic upon a swing span when the lifting device is improperly adjusted.

**End Lift.** The mechanism consisting of wedges, toggles, link-and-roller, rocker-and-eccentric or other devices combined with shafts, gears, or other operating parts requisite to remove the camber or "droop" of a swing span.

**End Post.** The end compression member of a truss, either vertical or inclined in position and extending from chord to chord, functioning to transmit the truss end shear to its end bearing.

**Epoxy.** A synthetic resin which cures or hardens by chemical reaction between components which are mixed together shortly before use.

**Equalizer.** A balance lever engaging the counterweight and the suspending cables of a vertical lift span as a means of adjustment and equalization of the stresses in the latter.

**Equilibrium.** In statics, the condition in which the forces acting upon a body are such that no external effect (or movement) is produced.

**Equivalent Uniform Load.** A load having a constant intensity per unit of its length producing an effect equal or practically equal to that of a live load consisting of vehicle axle or wheel concentrations spaced at varying distances apart, when used as a substitute for the latter in determining the stresses in a structure.

**Expansion Bearing.** A general term applied to a device or assemblage designed to transmit a reaction from one member or part of a structure to another and to permit the longitudinal movements resulting from temperature changes and superimposed loads without transmitting a horizontal force to the substructure.

The expansion bearing is designed to permit movement by overcoming sliding, rolling or other friction conditions. In general, provision is made for a movement equal to 1¼" in 100', thus providing for ordinary irregularities in field erection and adjustment.

**Expansion Dam.** The part of an expansion joint serving as an end form for the placing of concrete at a joint. Also applied to the expansion joint device itself.

**Expansion Joint.** A joint designed to provide means for expansion and contraction movements produced by temperature changes, loadings or other agencies.

**Expansion Rocker.** An articulated assemblage forming a part of the movable end of a girder or truss and facilitating the longitudinal movements resulting from temperature changes and superimposed loads. Apart from its hinge connection the rocker proper is a cast or built-up member consisting essentially of a circular segment integrally joined by a web-like portion to a hub fitted for hinge action either with a pin hole or by having its ends formed into trunnions. In its service operation the rocker is commonly supported upon a shoe plate or pedestal. Strictly speakir is is a segment of a roller. A short cast o ıp member hinged at both ends, or instea d at one end and provided with a circular nt or spherical type bearing at the other to facilitate expansion and contraction on other longitudinal rotational movements.

**Expansion Roller.** A cylinder so mounted that by revolution it facilitates expansion, contraction or other movements resulting from temperature changes, loadings or other agencies.

**Expansion Shoe.** (*Expansion Pedestal.*) An expansion bearing member or assemblage designed to provide means for expansion and contraction or other longitudinal movements. In general, the term "shoe" is applied to an assemblage of structural plates or plate-like castings permitting movement by sliding while the term "pedestal" is used to describe assemblages of castings or built-up members securing a somewhat greater total depth and providing for movement either by sliding or by rolling.

The masonry plate or casting is commonly held in a fixed position by anchor bolts and the superimposed shoe plate or pedestal is free to move longitudinally upon it or upon intervening rollers but is restrained from transverse movement either by a rib and slot, by pintles, by anchorage or by anchorage in combination with one of the first two mentioned. The term "bed plate" is sometimes used to designate the bottom portion of the assemblage.

**Extrados.** (*Back.*) 1. The curved surface of an arch farthest from its longitudinal construction axis or axes. 2. The curve defining the exterior surface of an arch.

**Eyebar.** A member consisting of a rectangular bar body with enlarged forged ends or heads having holes through them for engaging connecting pins.

An adjustable eyebar is composed of two sections fitted with upset threaded ends engaging a sleevenut or a turnbuckle.

**Eyebolt.** (*Ringbolt.*) A bolt having a forged eye at one end used, when installed in a structure, to provide means for making fast the end of a cable, a hooked rod or other part or portion of the bridge, or instead to provide a means of anchorage for unrelated equipment or structures.

A ringbolt is essentially an eyebolt fitted with a ring to serve the same purpose as described above for an eyebolt with added articulation.

## F

**Face Stones.** The stones exposed to view in the face surfaces of abutments, piers, arches, retaining walls or other stone structures.

**Face Wall.**

**Abutment.** See BREAST WALL.

**Spandrel Arch Structure.** The outermost spandrel walls providing the face surfaces of the completed structure. See SPANDREL ARCH.

**Factor of Safety.** A factor or allowance predicated by common engineering practice upon the failure stress or stresses assumed to exist in a structure or a member or part thereof. Its purpose is to provide a margin in the strength, rigidity, deformation and endurance of a structure or its component parts compensating for irregularities existing in structural materials and workmanship, uncertainties involved in mathematical analysis and stress distribution, service deterioration and other unevaluated conditions.

**Falsework.** A temporary wooden or metal framework built to support without appreciable settlement and deformation the weight of a structure during the period of its construction and until it becomes self-supporting. In general, the arrangement of its details are devised to facilitate the construction operations and provide for economical removal and the salvaging of material suitable for reuse.

**Fascia.** An outside, covering member designed on the basis of architectural effect rather than strength and rigidity although its function may involve both.

A light, stringer-like member spanning longitudinally between cantilever brackets which support large overhangs on girder or beam bridges.

**Fascia Girder.** As exposed outermost girder of a span sometimes treated architecturally or otherwise to provide an attractive appearance.

**Fatigue.** The tendency of a member to fail at a lower stress when subjected to cyclical loading than when subjected to static loading.

**Felloe Guard.** See WHEEL GUARD.

**Fender.** 1. A structure placed at an upstream location adjacent to a pier to protect it from the striking force, impact and shock of floating stream debris, ice floes, etc. This structure is sometimes termed an "ice guard" in latitudes productive of lake and river ice to form ice flows. 2. A structure commonly consisting of dolphins, capped and braced rows of piles or of wooden cribs either entirely or partially filled with rock ballast, constructed upstream and downstream from the center and end piers (or abutments) of a fixed or movable superstructure span to fend off water-borne traffic from collision with these substructure parts, and in the case of a swing span, with the span while in its open position.

**Fender Pier.** A pier-like structure which performs the same service as a fender but is generally more substantially built. These structures may be constructed entirely or in part of stone or concrete masonry. See GUARD PIER.

**Field Coat.** A coat of paint applied upon the priming or base coat or upon a coat subsequently applied and, generally, after the structure is assembled and its joints completely connected by bolts, rivets or welds. This application is quite commonly a part of the field erection procedure and is, therefore, termed field painting.

**Fill.** (*Filling.*) Material, usually earth, used for the purpose of raising or changing the surface contour of an area, or for constructing an embankment.

**Filler (Filler Plate).** In wooden and structural steel construction. A piece used primarily to fill a space beneath a batten, splice plate, gusset, connection angle, stiffener or other element.

**Filler Metal.** Metal prepared in wire, rod, electrode or other adaptable form to be fused with the structure metal in the formation of a weld.

**Filler Plate.** See FILLER.

**Fillet.** 1. A curved portion forming a junction of two surfaces which would otherwise intersect at an angle. 2. In metal castings and rolled structural shapes a fillet is used to disseminate and relieve the shrinkage or other stresses tending to overstress and, perhaps, rupture the junction material. In castings it may also provide means for movement to take place at locations where the rigidity of the mold would otherwise resist and obstruct this action. 3. In concrete construction the use of mitered fillets in internal corners of forms not only serves the purposes applying to castings but also facilitates both the placing of concrete and the subsequent removal of forms.

**Fillet Weld.** A weld joining intersecting members by depositing weld metal to form a near-triangular or fillet shaped junction of the surfaces of the members so joined. This weld serves to unite the intersecting surfaces of two elements of a member.

**Filling.** See FILL.

**Finger Dam.** Expansion joint in which the opening is spanned by meshing steel fingers or teeth.

**Fish Belly.** A term applied to a girder or a truss having its bottom flange or its bottom chord, as the case may be, constructed either haunched or bow-shaped with the convexity downward. See LENTICULAR TRUSS.

**Fixed-Ended Arch.** See VOUSSOIR ARCH.

**Fixed Bearing.** The plates, pedestals, or other devices designed to receive and transmit to the substructure or to another supporting member or structure the reaction stresses of a beam, slab, girder, truss, arch or other type of superstructure span.

The fixed bearing is considered as holding the so-termed "fixed end" of the structure rigidly in position, but in practice the clearance space commonly provided in the anchorage may permit a relatively small amount of movement.

**Fixed Bridge.** A bridge having its superstructure spans fixed in position except that provision may be made in their construction for expansion and contraction movements resulting from temperature changes, loadings, or other agencies.

**Fixed Span.** A superstructure span having its position practically immovable, as compared to a movable span.

**Flange.** The part of a rolled I-shaped beam or of a built-up girder extending transversely across the top and bottom edges of the web. The flanges are considered to carry the compressive and tensile forces that comprise the internal resisting moment of the beam, and may consist of angles, plates, or both.

**Flange Angle.** An angle used to form a flange element of a built-up girder, column, strut or similar member.

**Floating Bridge.** In general this term means the same as "Pontoon Bridge." However, its parts providing buoyancy and supporting power may consist of logs or squared timbers, held in position by lashing pieces, chains or ropes, and floored over with planks, or the bridge itself may be of hollow cellular construction.

**Floating Foundation.** A term sometimes applied to a "foundation raft" or "foundation grillage." Used to describe a soil-supported raft or mat foundation with low bearing pressures.

**Flood Gate.** (*Tide Gate.*) An automatically operated gate installed in a culvert or bridge waterway to prevent the ingress of flood or tide water to the area drained by the structure.

**Floor.** See DECK.

**Floor Beam.** A beam or girder located transversely to the general alignment of the bridge and having its ends framed upon the columns of bents and towers or upon the trusses or girders of superstructure spans. A floor beam at the extreme end of a girder or truss span is commonly termed an end floor beam.

**Floor System.** The complete framework of floor beams and stringers or other members supporting the bridge floor proper and the traffic loading including impact thereon.

**Flow Line.** The surface of a water course.

**Flux.** A material which prevents, dissolves, and removes oxides from metal during the welding process. It may be in the coating on a metal stick electrode or a granular mass covering the arc in submerged arc welding and protects the weld from oxidation during the fusion process.

**Footbridge.** (*Pedestrian Bridge.*) A bridge designed and constructed to provide means of traverse for pedestrian traffic only.

**Footing.** (*Footing Course, Plinth.*) The enlarged, or spread-out, lower portion of a substructure, which distributes the structure load either to the earth or to supporting piles. The most common footing is the concrete slab, although stone piers also utilize footings. Plinth refers to stone work as a rule. "Footer" is a local term for footing.

**Foot Wall.** See TOE WALL.

**Forms.** (*Form Work, Lagging, Shuttering.*) The constructions, either wooden or metal, providing means for receiving, molding and sustaining in position the plastic mass of concrete placed therein to the dimensions, outlines and details of surfaces planned for its integral parts throughout its period of induration or hardening.

The terms "forms" and "form work" are synonymous. The term "lagging" is commonly applied to the surface shaping areas of forms producing the intradoses of arches or other curved surfaces, especially when strips are used.

**Forms.** (SIP, Stay-in-Place.) A prefabricated metal concrete deck form that will remain in place after the concrete has set.

**Form Work.** See FORMS.

**Foundation.** The supporting material upon which the substructure portion of a bridge is placed. A foundation is "natural" when consisting of natural earth, rock or near-rock material having stability adequate to support the superimposed loads without lateral displacement or compaction entailing appreciable settlement or deformation. Also, applied in an imprecise fashion to a substructure unit.

**Consolidated Soil Foundation.** A foundation of soft soil rendered more resistant to its loads by (1) consolidating the natural material, (2) by the incorporation of other soil material (sand, gravel, etc.) into the soft material, and (3) by the injection of cementing materials into the soil mass which will produce consolidation by lapidification.

**Pile or Piled Foundation.** A foundation reinforced by driving piles in sufficient number and to a depth adequate to develop the bearing power required to support the foundation load.

**Foundation Excavation.** (*Foundation Pit.*) The excavation made to accommodate a foundation for a retaining wall, abutment, pier or other structure or element thereof.

**Foundation Grillage.** A construction consisting of steel, timber, or concrete members placed in layers. Each layer is normal to those above and below it and the members within a layer are generally parallel, producing a crib or grid-like effect. Grillages are usually placed under very heavy concentrated loads.

**Foundation Load.** The load resulting from traffic, superstructure, substructure, approach embankment, approach causeway, or other incidental load increment imposed upon a given foundation area.

**Foundation Pile.** A pile, whether of wood, reinforced concrete, or metal used to reinforce a foundation and render it satisfactory for the supporting of superimposed loads.

**Foundation Pit.** See FOUNDATION EXCAVATION.

**Foundation Seal.** A mass of concrete placed underwater within a cofferdam for the base portion of an abutment, pier, retaining wall or other structure to close or seal the cofferdam against incoming water from foundation springs, fissures, joints or other water carrying channels. See TREMIE.

**Foundation Stone.** The stone or one of the stones of a course having contact with the foundation of a structure.

**Frame.** A structure having its parts or members so arranged and secured that the entire assemblage may not be distorted when supporting the loads, forces, and physical pressures considered in its design. The framing of a truss relates to the design and fabrication of the joint assemblages.

**Framing.** The arrangement and manner of joining the component members of a bent, tower, truss, floor system or other portion of a bridge structure to insure a condition wherein each element and member may function in accord with the conditions attending its design. Framing must be interpreted as including both design and fabrication for the complete structure.

**Friction Roller.** A roller placed between parts or members intended to facilitate change in their relative positions by reducing the frictional resistance to translation movement.

**Frost Heave.** The upward movement of and force exerted by soil due to alternate freezing and thawing of retained moisture.

**Frost Line.** The depth to which soil may be frozen.

## G

**Galvanic Action.** Electrical current between two unlike metals.

**Gauge.** The distance between parallel lines of rails, rivet holes, etc. A measure of thickness of sheet metal or wire.

**Girder.** A flexural member which is the main or primary support for the structure, and which usually receives loads from floor beams and stringers.

Any large beam, especially if built up.

**Girder Bridge.** A bridge whose superstructure consists of two or more girders supporting a separate floor system of slab and floor beams, or slab, stringer, and floor beam, as differentiated from a multi-beam bridge or a slab bridge.

Any bridge utilizing large, built-up steel beams, prestressed concrete beams, or concrete box girders.

With reference to the vertical location of the floor system, plate girder spans are divided into two types, viz.:

1. Through bridges having the floor system near the elevation of the bottom flanges, whereby traffic passes between the top flanges.

2. Deck bridges having the floor system at or above the elevation of the top flanges whereby traffic passes above the girders.

**Girder Span.** A span in which the major longitudinal supporting members are girders. It may be simple, cantilever or continuous in type.

**Gothic Arch.** (*Pointed Arch.*) An arch in which the intrados surface is composed of two equal cylinder segments intersecting obtusely at the crown.

The Tudor Arch is a modification of the Gothic, produced by the introduction of shorter radius cylinder segments at the haunches thus rendering it a four-centered form or type.

**Grade Crossing.** A term applicable to an intersection of two or more highways, two railroads or one railroad and one highway at a common grade or elevation; now commonly accepted as meaning the last of these combinations.

**Grade Intersection.** The location where a horizontal and an inclined length of roadway or, instead, two inclined lengths meet in profile. To provide an easy transition from one to the other they are connected by a vertical curve and the resulting profile is a sag or a summit depending upon whether concaved or convexed upward.

**Grade Separation.** A term applied to the use of a bridge structure and its approaches to divide or separate the crossing movement of vehicular, pedestrian or other traffic, by confining portions thereof to different elevations. See OVERPASS.

**Gradient.** The rate of inclination of the roadway and/or sidewalk surface(s) from horizontal applying to a bridge and its approaches. It is commonly expressed as a percentage relation of horizontal to vertical dimensions.

**Gravity Wall.** See RETAINING WALL.

**Grillage.** A platform-like construction or assemblage used to insure distribution of loads upon unconsolidated soil material. See FOUNDATION GRILLAGE.

A frame composed of I-beams or other structural shapes rigidly connected and built into a masonry bridge seat, skewback or other substructure support to insure a satisfactory distribution of the loads transmitted by the superstructure shoes, pedestals, or other bearing members.

**Grout.** A mortar having a sufficient water content to render it a free-flowing mass, used for filling (grouting) the interstitial spaces between the stones or the stone fragments (spalls) used in the "backing" portion of stone masonry; for fixing anchor bolts and for filling cored spaces in castings, masonry, or other spaces where water may accumulate.

**Guard Pier.** (*Fender Pier.*) A pier-like structure built at right angles with the alignment of a bridge or at an angle therewith conforming to the flow of the stream current and having adequate length, width, and other provisions to protect the swing span in its open position from collision with passing vessels or other water-borne equipment and materials. It also serves to protect the supporting center pier of the swing span from injury and may or may not be equipped with a rest pier upon which the swing span in its open position may be latched. The type of construction varies with navigation and stream conditions from a simple pile and timber structure or a wooden crib-stone ballasted structure to a solid masonry one, or to a combination construction. In locations where ice floes or other water-borne materials may accumulate upon the upstream pier end, a cutwater or a starling is an essential detail. See FENDER PIER.

**Guard Railing.** (*Guard Rail, Guard Fence, Protection Railing.*) A fencelike barrier or protection built within the roadway shoulder area and intended to function as a combined guide or guard for the movement of vehicular and/or pedestrian traffic and to prevent or hinder the accidental passage of such traffic beyond the berm line of the roadway.

**Guide.** A member or element of a member functioning to hold in position and direct the movement of a moving part.

**Guide Roller.** A roller fixed in its location or position and serving both as a friction roller and as a pilot or guide for a part or member in contact with it.

**Gusset.** A plate serving to connect or unite the elements of a member or the members of a structure and to hold them in correct alignment and/or position at a joint. A plate may function both as a gusset and splice plate while under other conditions it may function as a gusset and stay plate. See SPLICE PLATE and STAY PLATE.

**Gutter.** See DRAIN.

**Gutter Grating.** A perforated or barred cover placed upon an inlet to a drain to prevent the entrance of debris gathered and brought to the inlet by the water stream.

**Guy.** A cable, chain, rod or rope member serving to check and control undulating, swaying or other movements, or to hold a fixed alignment or position a structure or part thereof by having one of its ends bolted, clamped, tied or otherwise fastened upon it, the other end being secured upon a part or member of the structure or upon a disconnected anchorage.

## H

**H-Beam.** (*H-Pile.*) A rolled steel bearing pile having an H-shaped cross section.

**Hand Hole.** Holes provided in cover plates of built-up box sections to permit access to the interior for maintenance and construction purposes.

**Hand Operated Span.** A manpower-operated movable span to which the force for operating is applied upon a capstan, winch, windlass or wheel.

The terms "Hand Draw Bridge," "Hand Swing Bridge" and "Lever Swing Bridge" are applied to swing spans of hand-operated type.

**Hand Rail.** See RAILING.

**Hanger.** A tension element or member serving to suspend or support a member attached thereto. A tension member, whether a rod, eyebar, or built-up member supporting a portion of the floor system of a truss, arch or suspension span. In suspension bridge construction wire cable is used and the complete member is commonly termed a "suspender."

**Haunch.** A deepening of a beam or column, the depth usually being greatest at the support and vanishing towards or at the center. The curve of the lower flange or surface may be circular, elliptic, parabolic, straight or stepped.

**Head.** A measure of water pressure expressed in terms of an equivalent weight or pressure exerted by a column of water. The height of the equivalent column of water is the head.

**Headwater.** The depth of water at the inlet end of a pipe, culvert, or bridge waterway.

**Headway.** See CLEAR HEADWAY.

**Heat Treatment.** Any of a number of various operations involving heating and cooling that are used to impart specific properties to metals. Examples are tempering, quenching, annealing, etc.

**Heel of Span.** The rotation end of a bascule span.

**Heel Stay.** See SHEAR LOCK.

**Hemispherical Bearing.** A bearing which utilizes the ball and socket principle by having male and female spherical segments forming the bearing areas or surfaces of the interlocking elements, thus providing for movements by revolution in any direction.

In order to insure accurate adjustment of the mating elements it is essential that a pintle or other self-centering device be provided as a part of the construction details.

**Hinged Joint.** A joint constructed with a pin, cylinder segment, spherical segment or other device permitting movement by rotation.

**Hip Joint.** (*The Hip of Truss.*) The juncture of the inclined end post with the end top chord member of a truss. In the truss of a swing span, the juncture of the inclined end post located adjacent to the center of span, with the combined top chord and the connecting tie member between the swing span arms, is designated an "interior hip joint" or an "interior hip of truss."

**Hip Vertical.** The vertically placed tension member engaging the hip joint of a truss and supporting the first panel floor beam in a through truss span, or instead, only the bottom chord in a deck truss span.

**Hook Bolt.** 1. A bolt having a forged hook at one end used for essentially the same purposes as described for an eyebolt. See EYEBOLT. 2. A bolt having its head end bent at or nearly at a right angle with its body portion and, when in use, acting as a clamp.

**Howe Truss.** A truss of the parallel chord type originally adapted to wooden bridge construction but with the later development of metal bridge trusses it was adopted only to a limited extent due to the uneconomical use of metal in its compression members. The web system is composed of vertical (tension) rods at the panel points with an X pattern of diagonals.

**Hydrolysis.** A chemical process of decomposition in the presence of elements of water.

**Hydroplaning.** Loss of contact between a tire and the deck surface when the tire planes or glides on a film of water covering the deck.

## I

**Ice Guard.** See FENDER.

**Impact.** As applied to bridge design—a dynamic increment of stress equivalent in magnitude to the difference between the stresses produced by a static load when quiescent and by a load moving in a straight line.

**Impact Load.** (*Impact Allowance.*) A load allowance or increment intended to provide for the dynamic effect of a load applied in a manner other than statically.

**Indeterminate Stress.** A stress induced by the incorporation of a redundant member in a truss or of an additional reaction in a beam rendering stress distributions indeterminate by the principles of statics.

In redundant beams or trusses the distribution of the stresses depends upon the relative stiffnesses or areas of the members.

**Inelastic Compression.** See COMPRESSION (INELASTIC).

**Inspection Ladders.** (*Inspection Platforms and Walks.*) Special devices or appliances designed to afford a safe and efficient means for making inspections and tests to determine the physical condition of a structure and to facilitate repair operations incident to its maintenance which must include these service conveniences. To prevent displacement they will be, in general, rigidly fixed upon the structure. However, certain types of structures are adapted to the use of movable platform devices for suspension from the railings or other parts which are or may be adapted thereto.

The term "catwalk" is applied to narrow permanent walks supported, usually, by brackets or by hangers and located below and/or above the bridge floor. This term is also applied to temporary walks used in the construction of suspension and other types of bridges as utilities facilitating the movements of labor and materials, and the supervision and inspection operations.

**Intercepting Ditch.** A ditch constructed to prevent surface water from flowing in contact with the toe of an embankment or causeway or down the slope of a cut.

**Intergranular Pressure.** Pressure between soil grains.

**Intermittent Weld.** A noncontinuous weld commonly composed of a series of short welds with intervening spaces arranged with fixed spacing and length.

**Intrados.** (*Soffit.*) The curved surface of an arch nearest its longitudinal (constructional) axis or axes. Properly speaking the intrados is the curve defining the interior surface of the arch.

## J

**Jack Stringer.** The outermost stringer supporting the bridge floor in a panel or bay. It is commonly of less strength than a main stringer.

**Joint.** In Stone Masonry. The space between individual stones.

In Concrete Construction. The divisions or terminations of continuity produced at predetermined locations or by the completion of a period of construction operations. These may or may not be open.

In a Truss or Frame Structure. (1) A point at which members of a truss or frame are joined, (2) the composite assemblage of pieces or members around or about the point of intersection of their lines of action in a truss or frame.

## K

**Keystone.** A stone of the crown string course of an arch. However, this term is most commonly applied to the symmetrically shaped wedgelike stone located in a head ring course at the crown of the arch, which thus exposed to view produces desired architectural effects. This head ring stone commonly extends short distances above and below the extradosal and intradosal limits of the voussoirs of adjoining string courses. The final stone placed, thereby closing the arch.

**King-Post.** (*King Rod.*) The post member in a "King-post" type truss or in a "King-post" portion of any other type of truss.

**King-Post Truss.** A truss adapted to either wooden or metal bridge construction. It is composed of two triangular panels with a common vertical. A beam or chord extends the full truss length.

In the through form of this truss the inclined members are struts and the vertical or King-post is a hanger. In the deck truss, the two inclined members become tie (tension) members and the vertical becomes a post (compression) member.

The King-post truss is the simplest of trusses belonging to the triangular system. However, it is described with equal accuracy as a trussed girder.

**K-Truss.** A truss having a web system wherein the diagonal members intersect the vertical members at or near the mid-height. When thus arranged the assembly in each panel forms a letter "K"; hence the name "K-Truss."

**Knee Brace.** A member usually short in length, engaging at its ends two other members which are joined to form a right angle or a near-right angle. It thus serves to strengthen and render more rigid the connecting joint.

**Knee Wall.** A return of the abutment backwall at its ends to enclose the bridge seat on three of its sides. The returned ends may or may not serve to retain a portion of the bridge approach material, but do hide the bridge seat, beam ends, and bearings.

**Knuckle.** An appliance forming a part of the anchorage of a suspension bridge main suspension member permitting free longitudinal movement of the anchorage chain at locations where it changes its direction and providing for elastic deformations induced by temperature changes and the pull exerted by the suspension member.

## L

**Lacing.** See LATTICE.

**Ladle Analysis.** (*Ladle Test, Check Analysis.*) As applied to the chemical determination of the constituents of steel or other ferrous metals, the terms "ladle analysis" and "ladle test" are synonymous and are used to designate the analysis of drillings or chips taken from the small ingot or ingots cast from a spoon sample taken from each melt during the pouring (teeming) operation.

The term "check analysis" is applied to the analysis of drillings taken from the finished material after being rolled, forged or otherwise worked. It is primarily intended as a check determination of the results secured from the ingots made at the furnace. Specifications may provide a tolerance or margin of variation between the ingot and the finished material analyses.

**Lagging.** See FORMS.

**Laminated Timber.** Timber planks glued together to form a larger member. Laminated timber is used for frames, arches, beams, and columns.

**Lap Joint.** A joint in which a splice is secured by fixing two elements or members in a position wherein they project upon or overlap each other.

**Latch.** (*Latch Block.*) The device or mechanism commonly provided at one or both ends of a swing span to hold the span in its correct alignment when in its closed position, and in readiness for the application of the end wedges or lifts.

**Latch Lever.** A hand-operated lever attached by a rod, cable or chain to the latching device of a movable span and used to engage and to release the latch.

**Lateral Bracing.** (*Lateral System.*) The bracing assemblage engaging the chords and inclined end posts of truss and the flanges of plate girder spans in the horizontal or inclined planes of these members to function in resisting the transverse forces resulting from wind, lateral vibration, and traffic movements tending to produce lateral movement and deformation. See BRACING.

**Lattice.** (*Latticing, Lacing.*) An assemblage of bars, channels, or angles singly or in combination bolted, riveted or welded in inclined position upon two or more elements of a member to secure them in correct position and assure their combined action. When the bars form a double system by being inclined in opposite directions the assemblage is termed "double lattice." When so arranged the bars are commonly connected at their intermediate length intersections.

**Lattice Truss.** In general, a truss having its web members inclined but more commonly the term is applied to a truss having two or more web systems composed entirely of diagonal members at any interval and crossing each other without reference to vertical members. Vertical members when used perform the functions of web stiffeners. They may be utilized for connecting vertically placed brace frames to the girders.

**Leaf.** The portion of a bascule bridge which forms the span or a portion of the span of the structure.

**Ledge Course.** In masonry or concrete construction, a course forming a projection beyond the plane of a superimposed course or courses. The projecting portion may be wash dressed to permit an unobstructed flow of rain water down the wall surface. A ledge course differs from a belt or string course in having a projection only upon its topmost bed. This construction is also known as a "Ledger Course."

**Ledge Rock.** See BED ROCK.

**Lenticular Truss.** (*Fish Belly Truss.*) A truss having polygonal top and bottom chords curved in opposite directions with their ends meeting at a common joint. The chords nearly coincide with parabolic arcs. In through spans the floor system is suspended from the joints of the bottom chord and the end posts are vertical.

**Lifting Girder.** A girder or girder-like member engaging the trusses or girders of a vertical lift span and to which the suspending cables are attached.

**Lift Span.** A superstructure span moved by revolution in a vertical plane or by lifting in a vertical direction to free a navigable waterway of the obstruction it presents to navigation. See MOVABLE BRIDGE.

**Link and Roller.** An adjustable device or assemblage consisting of a hinged strut-like link fitted with a roller at its bottom end, supported upon a shoe plate or pedestal and operated by a thrust strut serving to force it into a vertical position and to withdraw it therefrom. When installed at each outermost end of the girders or the trusses of a swing span their major function is to lift them to an extent that their camber or droop will be removed and the arms rendered free to act as simple spans. When the links are withdrawn to an inclined position fixed by the operating mechanism the span is free to be moved to an open position.

**Lintel Bridge.** A bridge having a single span or a series of spans composed of slabs of stone or reinforced concrete spanning the interval or intervals between its substructure elements.

**Lintel Stone.** A stone used to support a wall over an opening.

**Live Load.** A dynamic load such as traffic load that is supplied to a structure suddenly or that is accompanied by vibration, oscillation or other physical condition affecting its intensity.

**Loading Girder.** A term applied to the girder or girders of a center bearing type swing span, located above the pivot pier and functioning to concentrate the superimposed load upon the pivot.

**Location.** The longitudinal line assumed for construction purposes, which may or may not coincide with the center line of bridge; together with the gradients upon the bridge and its approaches established upon the construction plans and/or on the bridge site preparatory to construction operations.

**Lock Device.** A mechanism which locks the movable span of a bridge in its "closed" position and prevents movement to "open" position until released. The device on a swing span may also be used to lock the span in its "open" position at times when wind or other conditions render this prevention of movement desirable.

**Locking Mechanism.** A general term applied to the various devices used for holding in their closed or traffic service position a bascule, vertical lift or swing span of any type. This term applies not only to the locking or latching appliance but includes also the levers, shafts, gears or other parts incidental to their service operation.

**Longitudinal Bracing.** (*Longitudinal System.*) The bracing assemblage engaging the columns of trestle and viaduct bents and towers in perpendicular or slightly inclined planes located lengthwise with the bridge structure and functioning to resist the longitudinal forces resulting from traffic traction and momentum, wind or other forces tending to produce longitudinal movement and deformation. See BRACING.

## M

Margin. See TOLERANCE.

Masonry. A general term applying to abutments, piers, retaining walls, arches and allied structures built of stone, brick or concrete and known correspondingly as stone, brick or concrete masonry.

**Masonry Plate.** A steel plate or a plate-shaped member whether cast, rolled or forged, built into or otherwise attached upon an abutment, pier, column, or other substructure part to support the rocker, shoe, or pedestal of a beam, girder or truss span and to distribute the load to the masonry beneath.

**Mattress.** A mat-like protective covering composed of brush and poles, commonly willow, compacted by wire or other lashings and ties and placed upon river and stream beds and banks; lake, tidal or other shores to prevent erosion and scour by water movement action.

Meander. The tortuous channel that characterizes the serpentine curvature of a slow flowing stream in a flood plain.

Member. An individual angle, beam, plate forging, casting or built piece, with or without connected parts for joints, intended utlimately to become an integral part of an assembled frame or structure.

**Milled.** In steel fabrication, a careful grinding of an edge or surface to assure good bearing or fit.

**Mortar.** An intimate mixture, in a plastic condition, of cement, or other cementitious material with fine aggregate and water, used to bed and bind together the quarried stones, bricks, or other solid materials composing the major portion of a masonry construction or to produce a plastic coating upon such constructions.

The indurated jointing material filling the interstices between and holding in place the quarried stones or other solid materials of masonry construction. Correspondingly, this term is applied to the cement coating used to produce a desired surface condition upon masonry constructions and is described as the "mortar finish," "mortar coat," "floated face or surface," "parapet," etc.

The component of concrete composed of cement, or other indurating material with sand and water when the concrete is a mobile mass and correspondingly this same component after it has attained a rigid condition through hardening of its cementing constituents.

**Movable Bridge.** A bridge of any type having one or more spans capable of being raised, turned, lifted, or slid from its normal vehicular and/or pedestrian service location to provide for the passage of navigation. The movements of the superstructure may be produced either manually or by engine power.

**Bascule Bridge.** A bridge having a superstructure designed to swing vertically about a fixed or a moving horizontal axis. The axis may be the center of a hinge pin or trunnion, or it may be only a line fixing the center of a circular rotation combined with translation, (rolling lift bridge).

**Vertical Lift Bridge.** A bridge having a superstructure designed to be lifted vertically by cables or chains attached to the ends of the movable span and operating over sheaves placed upon the tops of masts or towers or by other mechanical devices functioning to lift the span to "open" position and to lower it into its "closed" position with its ends seated upon bridge seat pedestals.

**Pontoon Bridge.** A bridge ordinarily composed of boats, scows or pontoons so connected to the deck or floor construction that they are retained in position and serve to support vehicular and pedestrian traffic. A pontoon bridge may be so constructed that a portion is removable and thus serve to facilitate navigation. Modern floating bridges may have pontoons built integrally with the deck.

**Retractile Draw Bridge.** (*Traverse Draw Bridge.*) A bridge having a superstructure designed to move horizontally either longitudinally or diagonally from "closed" to "open" position, the portion acting in cantilever being counterweighted by that supported upon rollers.

**Rolling Lift Bridge.** A bridge of the bascule type devised to roll backward and forward upon supporting girders when operated throughout an "open and closed" cycle.

**Swing Bridge.** A bridge having a superstructure designed to revolve in a horizontal plane upon a pivot from its "closed" position to an "open" one wherein its alignment is normal or nearly normal to the original alignment. For a structure having its substructure skewed the design commonly provides for revolution in one direction only and through an arc less than 90°. The superstructure is balanced upon a center and its ends acting as cantilevers when the end bearings are released may be either equal in length or unequal with the shorter one counterweighted to permit free revolution movement. A swing bridge with its end bearings released may be supported: (1) upon a single center bearing; (2) upon a circular rim or drum supported upon rollers and (3) upon a center bearing and rim in combination.

**Movable Span.** A general term applied to a superstructure span designed to be withdrawn, swung, lifted or otherwise moved longitudinally, horizontally or vertically to free a navigable waterway of the obstruction it presents to navigation.

**Mud Sill.** A single piece of timber or a unit composed of two or more timbers placed upon a soil foundation as a support for a single column, a framed trestle bent, or other similar member of a structure.

A load distribution piece aligned with and placed directly beneath the sill piece of a framed bent is termed a "Sub-sill" although it may serve also as a mud sill.

## N

**N-Truss.** See PRATT TRUSS.

**Natural Slope.** See ANGLE OF REPOSE.

**Neat Line.** (*Neat Surface.*) The general alignment position or the general surface position of a face or other surface exlusive or regardless of the projections of individual stones, belts, belt courses, copings or other incidental or ancillary projections in a masonry structure.

**Neutral Axis.** The axis of a member in bending along which the strain is zero. On one side of the neutral axis the fibers are in tension, on the other side in compression.

**Normal Roadway Cross Section.** The roadway cross section with its crown in countradistinction to the superelevated cross sections used upon horizontal curves of different degrees of curvature and the transition lengths required for their development.

**Nose.** A projection acting as a cut water on the upstream end of a pier. See STARLING.

**Notch Effect.** Stress concentration caused by an abrupt discontinuity or change in section. Such concentrations may have a marked effect on fatigue strength of a member.

## O

**Operator's House.** (*Operator's Cabin.*) The building containing the power plant and operating machinery and devices required for the operator's (bridge tender's) work in executing the complete cycle of opening and closing a movable bridge span.

**Overpass.** (*Underpass.*) The applications of these terms are definitely indicated by their constructions. For any given combination of highways, railways, and canals, the basic element is a separation of grades. The use of these terms is fixed by the relative elevations of the traffic ways involved; for the lower roadway, the structure is an underpass; for the upper roadway, an overpass.

## P

**Packing Ring.** See SEPARATOR.

**Paddleboard.** Striped, paddle-shaped signs or boards placed on the roadside in front of a narrow bridge as a warning.

**Panel.** (*Sub-Panel.*) The portion of a truss span between adjacent points of intersection of web and chord members and, by common practice, applied to intersections upon the bottom chord. A truss panel divided into two equal or unequal parts by an intermediate web member, generally by a subdiagonal or a hanger, forms the panel division commonly termed "subpanels."

**Panel Point.** The point of intersection of primary web and chord members of a truss.

**Parabolic Truss.** (*Parabolic Arched Truss.*) A polygonal truss having its top chord and end post vertices coincident with the arc of a parabola; its bottom chord straight and its web system either triangular or quadrangular.

**Parapet.** A wall-like member composed of brick, stone or reinforced concrete construction upon the retaining wall portion of an approach cut, embankment or causeway or along the outermost edge of the roadway or the sidewalk portion of a bridge to serve as a protection to vehicular and/or pedestrian traffic. While the terms balustrade and parapet are used, in a measure, synonymously, the latter is commonly regarded as applying to barriers of the block type without openings within the body portion. See BALUSTRADE.

**Parker Truss.** See PRATT TRUSS.

**Pedestal.** A cast or built-up metal member or assemblage functioning primarily to transmit load from one member or part of a structure to another member or part. A secondary function may be to provide means for longitudinal, transverse or revolution movements.

A block-like construction of stone, concrete or brick masonry placed upon the bridge seat of an abutment or pier to provide a support for the ends of the beams.

**Pedestrian Bridge.** See FOOT BRIDGE.

**Penetration.** When Applied to Creosoted Lumber. The depth to which the surface wood is permeated by the creosote oil.

When Applied to Welding. The depth to which the surface metal of the structure part (Structure metal) is fused and coalesced with the fused weld metal to produce a weld joint. See WELD PENETRATION.

When Applied to Pile Driving. The depth a pile tip is driven into the ground.

**Pier.** A structure composed of stone, concrete, brick, steel or wood and built in shaft or block-like form to support the ends of the spans of a multi-span superstructure at an intermediate location between its abutments.

The following types of piers are adapted to bridge construction. The first three are functional distinctions, while the remaining types are based upon form or shape characteristics.

**Anchor Pier.** A pier functioning to resist an uplifting force, as for example: The end reaction of the anchor arm of a cantilever bridge. This pier functions as a normal pier structure when subjected to certain conditions of superstructure loading.

**Pivot Pier.** Center Pier. A term applied to the center bearing pier supporting a swing span while operating throughout an opening-closing cycle. This pier is commonly circular in shape but may be hexagonal, octagonal or even square in plan.

**Rest Pier.** A pier supporting the end of a movable bridge span when in its closed position.

**Cylinder Pier.** A type of pier produced by sinking a cylindrical steel shell to a desired depth and filling it with concrete. The foundation excavation may be made by open dredging within the shell and the sinking of the shell may proceed simultaneously with the dredging.

**Dumbbell Pier.** A pier consisting essentially of two cylindrical or rectangular shaped piers joined by a web constructed integrally with them.

**Hammerhead Pier.** (*Tee Pier.*) A pier with a cylindrical or rectangular shaft, and a relatively long, transverse cap.

**Pedestal Pier.** A structure composed of stone, concrete or brick built in block-like form—supporting a column of a bent or tower of a viaduct. Foundation conditions or other practical considerations may require that two or more column supports be placed upon a single base or footing section. To prevent accumulation of stream debris at periods of high water or under other conditions the upstream piers may be constructed with cut-waters and in addition the piers may be connected by an integrally built web between them. When composed only of a wide blocklike form, it is called a wall or solid pier.

**Pile Pier or Bent.** A pier composed of driven piles capped or decked with a timber grillage or with a reinforced concrete slab forming the bridge seat.

**Rigid Frame Pier.** Pier with two or more columns and a horizontal beam on top constructed to act like a frame.

**Pier Cap.** (*Pier Top.*) The topmost portion of a pier. On rigid frame piers, the term applies to the beam across the column tops. On hammerhead and tee piers, the cap is a continuous beam.

**Pilaster.** A column-like projection upon a face surface rarely intended to serve as a structural member but instead functioning as an architectural treatment to relieve the blankness of a plane surface.

**Pile.** A rod or shaft-like linear member of timber, steel, concrete, or composite materials driven into the earth to carry structure loads thru weak strata of soil to those strata capable of supporting such loads. Piles are also used where loss of earth support due to scour is expected.

**Bearing Pile.** One which receives its support in bearing through the tip (or lower end) of the pile.

**Friction Pile.** One which receives its support through friction resistance along the lateral surface of the pile.

**Sheet Piles.** Commonly used in the construction of bulkheads, cofferdams, and cribs to retain earth and prevent the inflow of water, liquid mud, and fine grained sand with water, are of three general types, viz.: (1) Timber composed of a single piece or of two or more pieces spiked or bolted together to produce a compound piece either with a lap or a tongued and grooved effect. (2) Reinforced concrete slabs constructed with or without lap or tongued and grooved effect. (3) Rolled steel shapes with full provision for rigid interlocking of the edges.

**Pile Cap.** Concrete footings for a pier or abutment supported on piles. Also applied to the concrete below the pile tops when footing reinforcing steel is placed completely above the piles.

**Pile Cut-Off.** The portion of a pile removed or to be removed from its driven butt end to secure the elevation specified or indicated.

**Pile Shoe.** A metal piece fixed upon the point or penetration end of a pile to protect it from injury in driving and to facilitate penetration in every dense earth material.

**Pile Splice.** One of the means of joining one pile upon the end of another to provide greater penetration length.

**Piling.** (*Sheet Piling.*) General terms applied to assemblages of piles in a construction. See PILE.

**Pin.** A cylindrical bar used as a means of connecting, holding in position, and transmitting the stresses of, the members forming a truss or a framed joint. To restrain the pin against longitudinal movement its ends are fitted with pin nuts, cotter bolts, or both. The nuts are commonly of the recessed type taking bearing at their edges upon the assemblage of members. To prevent the loosening of the nuts and the displacement of the pins by vibration, joint movements, and other service conditions, the pin ends may be burred or they may be fitted with cotters.

**Pin-Connected Truss.** A general term applied to a truss of any type having its chord and web members connected at the truss joints by pins.

**Pinion.** The small driving gear on the powertrain of a movable bridge.

**Pinion Bracket.** The frame supporting the turning pinion with its shaft and bearings upon the drum girder or the loading girder of a swing span.

**Pin Joint.** A joint in a truss or other frame in which the members are assembled upon a cylindrical pin.

**Pin Packing.** An arrangement of truss members on a pin at a pinned joint.

**Pin Plate.** A plate or shape riveted or otherwise rigidly attached upon the end of a member to secure a desired bearing upon a pin or pin-like bearing; to develop and distribute the stress of the joint and/or secure additional strength and rigidity in the member.

**Pintle.** A small steel pin or stud, engaging the rocker in an exansion bearing, thereby permitting rotation, transferring shear, and preventing translation.

**Pitch.** The longitudinal spacing between rivets, studs, bolts, holes, etc., which are arranged in a straight line.

**Plate Girder.** An I-shaped beam composed of a solid plate web with either flange plates or flange angles bolted, riveted or welded upon its edges. Additional cover plates may be attached to the flanges to provide greater flange area.

**Plinth.** See FOOTING.

**Plinth Course.** The course or courses of stone forming the base portion of an abutment, pier, parapet or retaining wall and having a projection or extension beyond the general surface of the main body of the structure. See also BASE and FOOTING.

**Plug Weld.** (*Slot Weld.*) A weld joining two elements of a member or two members so assembled that an area of contact will be secured and the weld produced by depositing weld metal within circular, square, slotted or other shaped holes cut through one or more of the elements or members. This weld serves to unite the elements of a member or to join the members intersecting at truss at other joints of a structure.

**Pointed Arch.** See GOTHIC ARCH.

**Pointing.** The operations incident to the compacting of the mortar in the outermost portion of a joint and the troweling or other treatment of its exposed surface to secure water tightness or desired architectural effect or both.

**Polygonal Truss.** A general term applied to a truss of any type having an irregular or "broken" alignment of straight top chord members which forms with the end posts and the bottom chord the perimeter of a polygon.

**Pony Truss.** A general term applied to a truss having insufficient height to permit the use of an effective top chord system of lateral bracing above the bridge floor.

**Pop-Out.** Conical fragment broken out of concrete surface. Normally about one inch in diameter. Shattered aggregate particles usually found at bottom of hole.

**Portable Bridge.** A bridge so designed and constructed that it may be readily erected for a temporary communication-transport service; disassembled and its members again reassembled and the entire structure rendered ready for further service.

**Portal.** The clear unobstructed space of a through bridge forming the entrance to the structure.

The entire portal member of the top chord bracing which fixes the uppermost limit of the vertical clearance. See BRACING. The portal of a skew bridge is described as a "skew portal."

**Post.** A term commonly applied to a relatively short member resisting compressive stresses, located vertical or nearly vertical to the bottom chord of a truss and common to two truss panels. Sometimes used synonymously for column. See COLUMN.

**Posted.** A limiting dimension, speed, or loading, e.g., posted load, posted clearance, posted speed, indicating larger dimensions and higher speeds and loads can not be safely taken by the bridge.

**Pot Holes.** Small worn or distintegrated areas of bridge floor or approach surface concaved by the wearing action of vehicle wheels.

**Pratt Truss.** (*N-Truss.*) A truss with parallel chords and a web system composed of vertical posts with diagonal ties inclined outward and upward from the bottom chord panel points toward the ends of the truss except the counters required in midlength panels. The Parker Truss is an adaptation of the Pratt Truss by making the top chord polygonal in shape.

**Priming Coat.** (*Base Coat.*) The first coat of paint applied to the metal or other material of a bridge. For metal structures this is quite commonly a fabricating shop application and is, therefore, termed the "shop coat."

**Protection Fence.** See GUARD RAILING.

**Protection Railing.** See GUARD RAILING.

## Q

**Queen-Post Truss.** A parallel chord type of truss adapted to either timber or metal bridge construction, having three panels with one of the chords occupying only the length of the center panel. Unless center panel diagonals are provided, it is a trussed beam.

## R

**Rack.** A bar with teeth on one of its sides, designed to mesh with the gears of a pinion or worm. The rack is usually attached to the moving portion of a movable bridge and receives the motive power from the pinion.

**Radial Rod.** (*Spider Rod.*) A radially located tie rod connecting the roller circle of a rim-bearing swing span with the center pivot or center bearing casting.

**Radial Strut.** A radially located brace member of the drum construction of a rim-bearing swing span.

**Railing.** (*Handrail.*) A wooden, brick, stone, concrete or metal fence-like construction built at the side of the roadway, or the sidewalk, upon the retaining wall portion of an approach cut, embankment, or causeway or at the outermost edge of the roadway or the sidewalk portion of a bridge to guard or guide the movement of both pedestrian and vehicular traffic and to prevent the accidental passage of traffic over the side of the structure.

The term "handrail" is commonly applied only to railing presenting a latticed, barred, balustered or other open web construction.

**Rake.** The slope, batter or inclination from a horizontal, vertical or other assumed plane, of the sides of an embankment or other inclined earth construction; the batter of a face or other surface of masonry; of the plane of a truss side of a tower or other portion of a bridge superstructure or of any member thereof.

**Ramp.** An inclined traffic-way leading from one elevation to another. The general term used to designate an inclined roadway and/or sidewalk approach to a bridge and commonly applied to a rather steep incline.

**Random Stone.** A general term applied to quarried stone block of any dimensions whether intended for ashlar or for random masonry construction.

**Range of Stress.** The algebraic difference between the minimum and maximum stresses in a member or in an element or part thereof either computed to be produced by a given condition of loading or produced by its actual service loading.

**Rebar.** A steel reinforcing bar.

**Redundant Member.** A member in a truss or frame which renders it a statistically indeterminate structure. The structure would be stable without the redundant member whose primary purpose is to reduce the stresses carried by the determinate structure.

**Re-Entrant Corner.** A corner with more than 180° of material and less than 180° of open space.

**Reinforcing Bar.** A steel bar, plain or with a deformed surface, which bonds to the concrete and supplies tensile strength to the concrete.

**Retaining Wall.** A structure designed to restrain and hold back a mass of earth.

**Buttressed Wall.** A retaining wall designed with projecting buttresses to provide strength and stability.

**Counterforted Wall.** A retaining wall designed with projecting counterforts to provide strength and stability.

**Gravity Wall.** A wall composed of brick, stone or concrete masonry designed to be stable against sliding and rotation (overturning) upon its foundation or upon any horizontal plane within its body by virtue of its shape and weight.

**Reinforced Concrete Cantilever Wall.** A wall consisting of a base section integral with stem constructed approximately at a right angle thereto giving its cross section a letter "L" or an inverted "T" shape. The stem portion resists the horizontal or other forces tending to produce overturning by acting as a cantilever beam.

**Rigid Frame Bridge.** A bridge with rigid or moment resistant connections between deck slabs or beams and the substructure walls or columns, producing an integral, elastic structure. The structure may be steel or concrete.

In general this type of bridge may be regarded as a form of arch or curved beam having its intermediate intradosal section or portion either straight or slightly curved and its end sections located normal to the straight portion or to the tangent of the curved one at its center length position.

**Rim Girder.** See DRUM GIRDER.

**Rim Plate.** Toothed or plain segmental rim on a rolling lift bridge.

**Ringbolt.** See EYEBOLT.

**Ring Stone.** See VOUSSOIR.

**Riprap.** Brickbats, stones, blocks of concrete or other protective covering material of like nature deposited upon river and stream beds and banks, lake, tidal or other shores to prevent erosion and scour by water flow, wave or other movement.

**Rise of an Arch.** For a symmetrical arch; the vertical distance from the chord through its springing lines to the intrados at its crown.

For an unsymmetrical arch, assumed to be in a normal vertical position, the vertical distances from its springing lines to the intrados at its crown.

**Riveted Joint.** (Bolted Joint.) A joint in which the assembled elements and members are united by rivets. The design of a riveted joint contemplates a proper distribution of its rivets to develop its various parts with relation to the stresses and the purposes which each must serve.

A bolted joint differs from a riveted one only in the use of bolts as the uniting medium instead of rivets. The conditions of design are generally the same, but different allowable unit stresses are employed.

**Roadway.** (*Travel Way.*) 1. The portion of the deck surface of a bridge intended for the use of vehicular or vehicular and pedestrian traffic. 2. The top surface portion of an approach embankment, causeway or cut intended for the general use of vehicular or vehicular and pedestrian traffic. In general, its width corresponds (1) to the distance curb to curb; (2) to the distance between the outside limits of sidewalks; or (3) to the width of the roadway pavement or traveled way when no curbs exist.

**Roadway Shoulder Area.** (*Shoulder Area.*) The portion or area of the top surface of an approach embankment, causeway, or cut immediately adjoining the roadway, used to accommodate stopped vehicles in emergencies and to laterally support base and surface courses.

**Rocker Bearing.** A cylindrical, sector-shaped member attached by a pin or trunnion at its axis location to the expansion end of a girder or truss and having line bearing contact upon its perimetral surface with the masonry plate or pedestal, thus providing for the longitudinal movements resulting from temperature changes and superimposed loads by a wheel-like translation.

The design condition that the entire reaction stress is concentrated upon a line contact renders it especially essential that the masonry plate or pedestal be accurately leveled and that the rocker be carefully adjusted to secure a uniform even bearing thereon. A relatively large percentage of this type of bearings lack correct adjustment.

**Rocker Bent.** A bent composed of metal, reinforced concrete or timber, hinged or otherwise articulated at one or both ends to provide the longitudinal movements resulting from temperature changes and the superimposed loads of the span or spans supported thereon.

**Rocker and Camshaft.** An adjustable bearing device or assemblage consisting of a rocker bearing combined with a camshaft, properly mounted and geared to produce by its rotation a vertical lifting action, reacting upon a shoe plate or pedestal fixed upon the bridge seat. When installed at each outermost end of the girders, or the trusses of a swing span, the lifting action raises them to an extent that their camber or droop will be removed and the areas rendered free to act as simple spans. When the camshafts are revolved through an angle of 180° from their total or full lift position the rocker bearings are released and lifted and the span is free to be moved to "open" position.

**Rolled Beams, Rolled Shapes.** See STRUCTURAL SHAPES, WIDE FLANGE BEAMS.

**Roller.** 1. A steel cylinder forming an element of a roller nest or any other device or part intended to provide movements by rolling contact. The so-termed "segmental roller" consisting essentially of two circular segments integrally joined by a web-like portion is used in the construction of roller nests requiring relatively large bearing length with the least practicable shoe plate area and a correspondingly decreased weight of metal in the entire assemblage. 2. One of the wheel-like elements forming the roller circle of a rim-bearing swing span.

**Roller Bearing.** A single roller or a group of rollers so housed as to permit movement of a part or parts of a structure thereon.

**Roller Nest.** A group of steel cylinders forming a part of the movable end of a girder or truss and located between the masonry plate and shoe or pedestal to facilitate the longitudinal movements resulting from temperature changes and superimposed loads. Commonly the rollers are assembled in a frame or a box. Roller nests may be used for other services than those herein described. The term "Expansion Rollers" is sometimes used synonymously for roller nest.

**Roller Track.** The circular track upon which the drum rollers of a rim-bearing swing span travel. This is sometimes described as the lower track.

**Roller Tread.** See TREAD PLATES.

**Rolling Lift Bridge.** See MOVABLE BRIDGE.

**Rubble.** Irregularly shaped pieces of stone in the undressed condition obtained from the quarry and commonly ranging in size from relatively small usable pieces to one-man or two-man stones. This term is also applied to large boulders and fragments requiring mechanical equipment for handling. When shaped ready for use in rubble masonry, this stone is commonly described as "worked" or "dressed" rubble.

**Run-Off.** As applied to bridge design, the portion of the precipitation upon a drainage (catchment) area which is discharged quickly by its drainage stream or streams and which, therefore, becomes a factor in the design of the effective water discharge area of a bridge. Run-off is dependent upon soil porosity (varied by saturated or frozen condition), slope or soil surfaces, intensity of rainfall or of melting snow conditions, and other pertinent factors.

## S

**Saddle.** A member located upon the topmost portion of the tower of a suspension bridge, designed to support the suspension cable or chain and to provide for its horizontal movements resulting from elastic deformations induced by temperature changes and the stresses incident to the service loadings.

**Safe Load.** The maximum loading determined by a consideration of its magnitudes and distributions of wheel, axle or other concentrations as productive of unit stresses in the various members and incidental details of a structure, permissible for service use, due consideration being given to the physical condition of the structure resulting from its previous service use.

**Safety Curb.** A narrow curb between 9 inches and 24 inches wide serving as a refuge or walkway for pedestrians crossing a bridge.

**Sag.** A deformation of an entire span; of any part of a span, or of one or more of its members from the horizontal, vertical, or inclined position intended as a condition of its original design and construction. This variation may result from elastic deformation of structural material; from irregularities produced by inadequate temporary supports during the progress of construction operations; or from incorrect adjustments and unworkmanlike procedures made a part of the work.

In existing structures sag may be attributable to (1) original construction irregularities; (2) to excessive stresses resulting from overloading; (3) to corrosion, decay or other deterioration of the structure materials, and (4) plastic flow of material.

The total deflection of the cable members of a suspension bridge. The so-termed "sag ratio" is the relation existing between the sag and the length of span.

**Sag Rod.** A rod usually fitted with threads and nuts at its ends; used to restrain a structure member from sagging due to its own weight or to external force or forces.

**Sash Brace.** (*Sash Stay, Sash Strut.*) A horizontal or nearly horizontal piece bolted or otherwise secured upon the side of a pile or framed bent between the cap and ground surface or the cap and sill, as the case may be, thus adding rigidity to the assemblage.

The horizontal member in a tier of bracing attached to a timber, reinforced concrete, or metal trestle bent or tower.

**Scab.** (*Scab Piece.*) A plank spiked or bolted over the joint between two members to hold them in correct adjustment and strengthen the joint.

A short piece of I-beam or other structural shape bolted, riveted or welded upon the flange and/or web of a metal pile to increase its resistance to penetration. Similarly, for the same purpose, a piece of dense hardwood fitted upon the flange and/or web and having bearing upon a lug angle at one or both its ends.

**Scour.** An erosion of a river, stream, tidal inlet, lake or other water bed area by a current, wash or other water in motion, producing a deepening of the overlying water, or a widening of the lateral dimension of the flow area.

**Screw Jack and Pedestal.** An adjustable device or assemblage consisting of a screw operated within a fixed nut and having upon its bottom end a pedestal-like bearing conjoined with it by a ball and socket or other equally adaptable articulation permitting its adjustment upon a shoe plate or pedestal fixed upon the bridge seat. When installed at each outermost end of the girders or the trusses of a swing span their major function is to lift them to an extent that their camber or droop will be removed and the arms rendered free to act as simple spans.

**Scupper.** (*Curb Inlet.*) An opening in the floor portion of a bridge, commonly located adjacent to the curb or wheel guard, to provide means for rain or other water accumulated upon the roadway surface to drain through it into the space beneath the structure. Bridges having reinforced concrete floors with concrete curbs may be effectively drained through scuppers located within the curb face surfaces.

**Scupper Block.** One of the short wooden pieces fixed between the wooden planks of a bridge floor and the bottom side of the wheel guard to provide open spaces beneath the latter for draining rain or other water accumulation from the floor surface.

**Seam Weld.** A weld joining the edges of two elements of a member or of two members placed in contact. This weld serves to form a continuous surface whether plane or curved, and to prevent infiltration of moisture between the parts. In general, it is not a stress carrying weld.

**Seat Angle.** (*Shelf Angle.*) A piece of angle attached upon the side of a column girder or other member to provide support for a connecting member either temporarily during its erection or permanently. The outstanding leg of the angle may be strengthened by a stiffener placed vertically beneath it.

**Segmental Girder and Track Girder.** These terms apply to the rolling lift type of bascule bridge combining circular rotation and translation movements in the "opening-closing" cycle.

The term "segmental girder" is used to designate one of the movable operating girders of a span or leaf to which a span girder or truss is rigidly attached. It commonly consists of a plate girder having its bottom flange curved to form a segment of a circle. This curved flange is fitted with tread castings which take line bearing contact upon the tread castings fitted upon the top flange of the supporting track girder with which they interlock to insure positive translation movement.

The term "track girder" is used to designate one of the plate girders or trusses intended to provide support for the movable span throughout an "opening-closing" cycle. Its tread castings fitted upon its top flange or chord form the track upon which the segmental girder moves by a rack and pinion-like action.

**Segmental Rim.** The curved rim or circular segment of a rolling lift bridge.

**Seizing.** The ligature of wire or other material applied upon a suspension bridge cable to hold the individual wires in satisfactory contact condition.

**Separator.** See SPREADER.

**Shafts.** Pieces conveying torsion stress only, which are, in general, used only in movable structures.

**Shear Lock.** (*Heel Stay, Tail-Lock.*) The device or mechanism provided at the heel of a bascule span to engage and hold the leaf in its closed position and prevent rotation.

**Sheave.** A wheel having a groove or grooves in its face surface. This term may be applied collectively to include both the sheave and its housing block.

**Sheave Girder.** A girder or girder-like member supporting the operating cable sheaves at the top of a tower of a vertical lift bridge.

**Sheave Hood.** A protecting covering placed above a sheave engaging the suspending cables of a vertical lift bridge to prevent accumulations of moisture, sleet and ice upon the sheave face.

**Sheet Pile Cofferdam.** In general a wall-like, watertight or nearly watertight barrier composed of driven timber or metal sheet piling constructed to surround the area to be occupied by an abutment, pier, retaining wall or other structure and permit unwatering of the enclosure so that the excavation for the preparation of a foundation and the abutment, pier or other construction may be produced in the open air. The alignment of the piles may be facilitated by the use of walers, struts and ties.

This type of dam is adapted to construction located in still or slow flowing, shallow water. Its watertightness is sometimes rendered more complete by depositing earth material against the exterior side of the dam.

**Sheet Piling.** (*Sheeting.*) A general or collective term used to describe a number of sheet piles taken together to form a crib, cofferdam, bulkhead, etc.

**Shelf Angle.** See SEAT ANGLE.

**Shim.** A comparatively thin piece of wood, stone, or metal inserted between two elements, pieces or members to fix their relative position and/or to transmit bearing stress.

**Shoe.** In general, a pedestal-shaped member at the end of a plate girder or truss functioning to transmit and distribute its loads to a masonry bearing area or to any other supporting area or member. A shoe may be a cast or a built-up member; the base plate or plate-like part of which is commonly termed the "shoe plate," which may take bearing directly upon a masonry plate or upon an intervening expansion device.

**Shore.** A strut or prop placed in a horizontal, inclined or vertical position against or beneath a structure or a portion thereof to restrain movement.

**Shoulder Area.** See ROADWAY SHOULDER AREA.

**Sidewalk.** The portion of the bridge floor area serving pedestrian traffic only and, for safety and convenience to its users, commonly elevated above the portion occupied by vehicles.

**Sidewalk Bracket.** As applied to metal structures: A trianguar shaped frame attached to and projecting from the outside of a girder, truss or bent to serve as a support for the sidewalk stringers, floor and railing or parapet. In general, these brackets are in effect a cantilevered extension of the floor beams and are commonly connected to them by bars or other tension pieces designed to sustain the bending moment at the junction plane.

As applied to reinforced concrete structures: A cantilever beam commonly triangular in shape, attached to and projecting from the outside of a girder, truss, or bent to serve as a support for the sidewalk floor slab and the railing or parapet.

**Sill.** (*Sill Piece.*) The base piece or member of a viaduct or trestle bent serving to distribute the column loads directly upon the foundation or upon mud sills embedded in the foundation soil transversely to the alignment of the bent.

**Silt.** Very finely divided siliceous or other hard and durable rock material derived from its mother rock through attritive or other mechanical action rather than chemical decomposition. In general, its grain size shall be that which will pass a Standard No. 200 sieve.

**Simple Span.** A superstructure span having, at each end, a single unrestraining bearing or support and designed to be unaffected by stress transmission to or from an adjacent span or structure.

**S-I-P Forms.** See FORMS.

**Skew Angle.** As applied to oblique bridges; the skew angle, angle of skew or simply "skew" is the acute angle subtended by a line normal to the longitudinal axis of the structure and a line parallel to or coinciding with the alignment of its end.

**Skewback.** The course of stones, in an abutment or pier, located at the extremity of an arch and having its beds inclined (battered) as required to transmit the stresses of the arch. The bed adjoining the voussoirs forming the first string course of the arch ring will be normal to the axis of the arch. The individual stones of the skewback course are designated "skewback stones."

A casting or a combination of castings; or a built-up member designed to function as a skewback.

**Skewback Shoe.** (*Skewback Pedestal.*) The shoe or pedestal member, transmitting the thrust of a trussed arch or a plate girder arch to the skewback course or cushion course of an abutment or pier. Skewback shoes and pedestals are commonly hinged.

**Slab.** A thick plate, usually of reinforced concrete, which supports load by flexure. It is usually treated as a widened beam.

**Slab Bridge.** A bridge having a superstructure composed of a reinforced concrete slab constructed either as a single unit or as a series of narrow slabs placed parallel with the roadway alignment and spanning the space between the supporting abutments or other substructure parts. The former is commonly constructed in place but the latter may be precast.

**Slag Inclusion.** Small particles of slag trapped inside a weld during the fusion process.

**Sleeve Nut.** A device used to connect the elements of an adjustable rod or bar member. It consists of a forging having an elongated nut-shaped body with right- and left-hand threads within its end portions, thus permitting its adjustment with a wrench to provide a desired tension in the member.

**Slenderness Ratio.** Measure of stiffness of a member, expressed as the length of the member divided by its radius of gyration.

**Slope.** A term commonly applied to the inclined surface of an excavated cut or an embankment.

**Slope Pavement.** (*Slope Protection.*) A thin surfacing of stone, concrete or other material deposited upon the sloped surface of an approach cut, embankment or causeway to prevent its disintegration by rain, wind or other erosive action.

**Slot Weld.** See PLUG WELD.

**Soffit.** See INTRADOS.

**Sole Plate.** A plate bolted, riveted, or welded upon the bottom flange of a rolled beam, plate girder, or truss to take direct bearing upon a roller nest, bearing pedestal, or masonry plate. It distributes the reaction of the bearing to the beam, girder, or truss member. The sole plate may also function as a combined sole and masonry plate at the fixed end of a beam, girder, or truss.

**Soldier Beam.** A steel pile driven into the earth with its butt end projecting, used as a cantilever beam to support horizontal lagging retaining an excavated surface.

**Spalls.** Circular or oval depression in concrete caused by a separation of a portion of the surface concrete, revealing a fracture parallel with or slightly inclined to the surface. Usually part of the rim is perpendicular to the surface.

The pieces of spalled concrete themselves.

**Span.** This term has various applications depending upon its use whether in design, in field construction, or in its common nontechnical application, viz.:

When applied to design of a beam, girder, truss or arch structure. The distance center to center of the end bearings or the distance between the lines of action of the reactions whether induced by substructure or other supporting members.

When applied to the field construction of substructure abutments and piers. The unobstructed space or distance between the faces of the substructure elements. For arch structures this length is measured at the elevation of the springing lines. These lengths or dimensions are commonly referred to as "clear span length." See CLEAR SPAN.

The complete superstructure of a single span bridge or a corresponding integral part or unit of a multiple span structure. This application of "span" is rendered more specific when subdivided into: (a) Fixed Span: A superstructure anchored in its location upon the substructure and (b) Movable Span: A superstructure intended to be swung or lifted to provide an unobstructed waterway space for the passage of waterborne traffic.

**Spandrel.** The space bounded by the arch extrados, the substructure abutments and/or pier(s), and the roadway surface or other elevation limit fixed by the construction details.

**Spandrel Column.** A column superimposed upon the ring or a rib of an arch span and serving as a support for the deck construction of an open spandrel arch. See OPEN SPANDREL ARCH.

**Spandrel Fill.** The filling material placed within the spandrel space of a spandrel arch.

**Spandrel Tie.** A wall or a beam-like member connecting the spandrel walls of an arch and securing them against bulging and other deformation. In stone masonry arches the spandrel tie walls served to some extent as counterforts. In reinforced concrete spandrel arch spans spandrel tie walls may likewise serve as counterforts. See TIE WALLS.

**Spandrel Wall.** A wall built upon an arch to function as a retaining wall for the spandrel fill and the roadway in a spandrel filled structure; but, when the spandrel is not filled, to support the floor system and its loads. In wide structures having unfilled spandrels one or more interior walls may be used, thus providing a cellular construction when combined with tie walls. See TIE WALLS.

**Specifications.** A detailed enumeration of the chemical and physical properties determining the quality of construction materials together with requirements for handling, shipping and storage thereof; the conditions governing the loads, load applications and unit stress considerations of bridge foundation, substructure and superstructure design; the development of construction details and their applications incident to fabrication; erecton or other constructon procedures pertinent to the production of serviceable bridge structures.

When general or so called "standard" specifications are used, it occasionally becomes necessary to supplement the requirements by items having specific application to a given bridge structure or group of structures. The special items may either designate and authorize departures from the "standard" or apply entirely to requirements and conditions not dealt with therein. The status of these supplemental or special specifications is commonly fixed by the "standard" specifications. Likewise the "standard" specification commonly recognizes the possibility of discrepancies between the specifications and the general plans and working (detail) drawings by fixing a coordination status for such occurrences.

**Spider.** The collar-like plate connecting the spider frame of a rim bearing or a combined rim and center bearing swing span to the pivot.

**Spider Frame.** The frame assemblage of struts, radial rods, spacer rings and roller adjusting devices holding the conical roller ring of a rim bearing or a combined rim and center bearing swing span in correct position with relation to the pivot.

**Spider Rod.** See RADIAL ROD.

**Splay Saddle.** A member at the anchorage ends of suspension bridge cables which permits the wires or strands to spread so that they may be connected to the anchorage.

**Splice.** This term has two applications depending upon its use whether in design or in shop and field construction, viz.:

When applied to design and the development of construction details: The joining or uniting of elements of a member, parts of a member or members of a structure to provide desired conditions for the transmittal of stress and the development of rigidity and general strength fulfilling the service requirements of the member or of the structure of which it is a part.

When applied to shop and field construction: the complete assemblage of parts used in producing the union of elements of a member or members of a structure.

**Splice Joint.** A joint in which the elements of a member or the members of a structure are joined by a splice plate or by a part or piece functioning to secure a required amount of strength and stability.

**Spreader.** 1. A cast or fabricated piece used to hold angles, beams, channels or fabricated pieces or parts in the locations or positions in which they function as parts of a member or structure. 2. A ring-like or sleeve-like piece placed upon a pin to hold the eyebars or other members assembled upon it in their correct member positions. This piece is sometimes described as a "pin-filler," or "packing ring."

**Springing Line.** The line within the face surface of an abutment or pier at which the intrados of an arch takes its beginning or origin.

**Starling.** An extension at the upstream end only, or at both the upstream and downstream ends of a pier built with surfaces battered thus forming a cutwater to divide and deflect the stream waters and floating debris and, correspondingly, when on the downstream end, functioning to reduce crosscurrents, swirl and eddy action which are productive of depositions of sand, silt and detritus downstream from the pier.

**Statics.** The branch of physical science which is concerned with bodies acted on by balanced forces. Therefore, these bodies are either at rest or static.

**Stay-In-Place Forms.** See FORMS.

**Stay Plate.** (*Tie Plate.*) A plate placed at or near the end of a latticed side or web of a compression or other member and also at intermediate locations where connections for members interrupt the continuity of the latticing. This plate serves to distribute the lattice bar stress to the elements of the member and adds stiffness and rigidity to joint assemblages.

**Stem.** The vertical wall portion of an abutment retaining wall, or solid pier. See also BREASTWALL.

**Stiffener.** An angle, tee, plate or other rolled section riveted, bolted or welded upon the web of a plate girder or other "built-up" member to transfer stress and to prevent buckling or other deformation.

A stiffener forged at its ends to fit upon the web and the web-legs of the flange angles of a plate girder is termed "crimped."

**Stiffening Girder, Stiffening Truss.** A girder or truss incorporated in a suspension bridge to function in conjunction with a suspension cable or chain by restraining the deformations of the latter and by distributing the concentrated or other irregularly distributed loads thus resisting and controlling the vertical oscillations of the floor system imparted to it by the cable or chain deformations.

**Stirrup.** In timber and metal bridges: A U-shaped rod, bar or angle piece providing a stirrup-like support for an element of a member or a member.

In reinforced concrete bridges: A U-shaped bar placed in beams, slabs or similar constructions to resist diagonal tension stresses.

**Stirrup Bolt.** A U-shaped rod or bar fitted at its ends with threads, nuts and washers and used to support streamer or other timber pieces of wooden truss structures suspended from the bottom chord.

**Stone Facing.** (*Stone Veneer, Brick Veneer.*) A stone or brick surface covering or sheath laid in imitation of stone or brick masonry but having a depth thickness equal to the width dimension of one stone or brick for stretchers and the length dimension for headers. The backing portion of a wall or the interior portion of a pier may be constructed of rough stones imbedded in mortar or concrete, cyclopean concrete, plain or reinforced concrete, brick bats imbedded in mortar, or even of mortar alone. The backing and interior material may be deposited as the laying of the facing material progresses to secure interlocking and bonding with it, or the covering material may be laid upon its preformed surface.

**Strain.** The distortion of a body produced by the application of one or more external forces and measured in units of length. In common usage, this is the proportional relation of the amount of distortion divided by the original length.

**Stress.** The resistance of a body to distortion when in a solid or plastic state and when acting in an unconfined condition. Stress is produced by the strain (distortion) and holds in equilibrium the external forces causing the distortion. It is measured in pounds or tons. Within the elastic limit the strain in a member of a structure is proportional to the stress in that member.

**Allowable Unit Stress.** As applied to the investigation of an existing structure in determining its adequacy for existing or prospective service; it is the stress per unit of area of the material of the entire structure or any portion or member thereof which is determined to be a safe unit for service use, due consideration being given to the quality of the material, physical condition, the adequacy of the construction details or other physical factors incident or pertinent to the service conditions to which they are or will be subjected and, if necessary, to the conditions contemplated to exist in the event of repair, replacement or strengthening operations.

**Unit Stress.** The stress per square inch (or other unit of surface or crosssectional area). The Allowable Unit Stress is: (a) Assumed in determining the composition and construction details of a memer or the members of a proposed structure, or (b) assumed for judging the safe load-capacity of an existing structure; while working stress is (c) produced in the members and parts of an existing structure when subjected to loads, impacts and other stress-producing elements and factors to which the structure is proposed to be or may have been subjected.

**Working Stress.** The unit stress in a member under service or design load.

**Stress Sheet.** A drawing showing a structure in skeletal form sufficient only to impart or suggest in conjunction with notations thereon its general makeup, major dimensions and the arrangement and composition of its integral parts. Special construction details may be shown by section views and sketches with or without dimensional data. Upon the skeletal outline of the structure or in tabulated form the drawing should show the computed stresses resulting from the application of a system of loads together with the design composition of the individual members resulting from the application of assumed unit stresses for the material or materials to be used in the structures. The assumed design load or loads should appear either in diagrammatic form with dimensions and magnitudes, or reference be made to readily available information relating thereto by a special note conspicuously displayed upon the drawing. A future investigation of a given structure to determine its reliability for a given load or combination of loads may be greatly facilitated and expedited by an adequate stress sheet record of its original design conditions.

**Stringer.** A longitudinal beam supporting the bridge deck, and in large bridges or truss bridges, framed into or upon the floor beams.

**Structural Members.** Basically these are of three types, viz.: (1) Ties: Pieces subject to axial tension only; (2) Columns or Struts: Pieces subject to axial compression only; (3) Beams: Pieces transversely loaded and subject to both shear and bending moment.

However, the arrangement of the members of a structure and the application of its design loads may embody combinations of these basic stress types.

**Structural Shapes.** As applied to bridge structures: The various types and forms of rolled iron and steel having flat, round, angle, channel, "I", "H", "Z" and other cross-sectional shapes adapted to the construction of the metal members incorporated in reinforced foundations, substructures and superstructures.

**Structural Tee.** A tee-shaped rolled member formed by cutting a wide flange longitudinally along the centerline of web.

**Strut.** A general term applying to a piece or member acting to resist compressive stress.

**Sub-Panel.** See PANEL.

**Subpunched and Reamed Work.** A term applied to structural steel shapes having rivet holes punched a specified dimension less in diameter than the nominal size of the rivets to be driven therein and subsequently reamed to a specified diameter greater than the rivet size.

This term is also applied to completely assembled and riveted members and structures in which the rivet holes have been produced by subpunching and reaming procedure.

**Substructure.** The abutments, piers, grillage or other constructions built to support the span or spans of a bridge superstructure whether consisting of beam, girder, truss, trestle or other type or types of construction.

**Sump.** A pit or tank-like depression or receptacle into which water is drained. The removal of the water so accumulated may be effected by pumping or by siphoning.

**Superelevation.** (*Curve Banking.*) The transverse inclination of the roadway surface within a horizontal curve and the relatively short tangent lengths adjacent thereto required for its full development. The purpose of superelevation is to provide a means of resisting or overcoming the centrifugal forces of vehicles in transit.

**Superstructure.** The entire portion of a bridge structure which primarily receives and supports highway, railway, canal, or other traffic loads and in its turn transfers the reactions resulting therefrom to the bridge substructure. The superstructure may consist of beam, girder, truss, trestle or other type or types of construction.

A superstructure may consist of a single span upon two supports or of a combination of two or more spans having the number and distribution of supports required by their types of construction, whether consisting of simple, continuous, cantilever, suspension, arch or trestle span-tower-bent construction.

**Surcharge.** An additional load placed atop existing earth or dead loads. In the case of abutments and retaining walls, the surcharge load is assumed to be replaced by an earth load of equivalent total weight.

**Suspended Span.** A superstructure span having one or both of its ends supported upon or from adjoining cantilever arms, brackets or towers, and designed to be unaffected by other stress transmission to or from an adjacent structure. The ordinary use of a suspended span is in connection with cantilever span construction.

**Suspender.** A wire cable, a metal rod or bar designed to engage a cable band or other device connecting it to the main suspension member of a suspension bridge at one end and a member of the bridge floor system at the other thus permitting it to assist in supporting the bridge floor system and its superimposed loads by transferring loads to the main suspension members of the structure.

A member serving to support another member in a horizontal or an inclined position against sagging, twisting or other deformation due to its own weight.

**Suspension Bridge.** A bridge in which the floor system and its incidental parts and appliances are supported in practically a horizontal position by being suspended upon cables which are supported at two or more locations upon towers and are anchored at their extreme ends. The cables constitute the main suspension members and commonly their anchorage may be one of three forms, viz.: (1) By extension of these members beyond the towers to the anchorages; (2) By fixing their ends upon the towers and backstaying the towers against overturning by the suspension members pulling upon them; (3) By an integral inclusion of the anchorages within the structure whereby the entire horizontal and vertical components of the main suspension member stresses are resisted by a rigid floor system construction functioning as a column, upon the extreme ends of which the main suspension members are securely connected. This form is commonly described as "self anchored."

**Suspension Cable.** (*Suspension Chain.*) One of the main members upon which the floor system of a suspension bridge is supported. Its ends may be fixed at the tops of towers which are backstayed to resist the horizontal components of the cable or chain stresses or instead it may rest upon saddles at the tops of two or more towers and be extended and fixed upon anchorage members. When the extension portions from the tops of towers to the anchorages do not directly support any part of the bridge floor, they function essentially as backstays; but when they engage floor suspenders located between the towers and anchorages they function as suspension cables for the end spans of the structure.

**Sway Anchorage.** (*Sway Cable.*) A guy, stay cable or chain attached at an intermediate length location upon the floor system of a suspension bridge and anchored upon the end portion of an abutment or pier or in the adjacent land surface to increase the resistance of the suspension span to lateral movement.

**Sway Brace.** 1. A piece bolted, or otherwise secured in an inclined position upon the side of a pile or frame bent between the cap and ground surface or the cap and sills, as the case may be, to add rigidity to the assemblage. See BRAC-

ING. 2. An inclined member in a tier of bracing forming a part of a timber, metal, or R/C bent or tower. 3. One of the inclined members of the sway bracing system of a metal girder or truss span. In plate girder construction the term X-brace is sometimes used.

**Sway Frame.** A complete panel or frame of sway bracing. See BRACING.

**Swedge Bolt.** See ANCHOR BOLT.

**Swing Span.** A superstructure span designed to be entirely supported upon a pier at its center, when its end supports have been withdrawn or released, and equipped to be revolved in a horizontal plane to free a navigable waterway of the obstruction it presents to navigation when in its normal traffic service position. See MOVABLE BRIDGE.

**Swing Span Pivot.** The center casting upon or about which the movable portion of a swing span revolves in making an opening-closing cycle.

In the center bearing type span, this casting functions not only as a pivotal member but also as the support for the movable span when the end lifting device is released.

In the rim-bearing type span this casting functions as a pivotal anchor member regulating the location of the movable parts throughout an opening-closing cycle but does not support the movable span.

In the combined center and rim-bearing type this casting functions as a support for a portion of the weight of the movable span when the end lifting device is released.

## T

**Tack Weld.** A weld of the butt, fillet or seam type intended only to fix an element of a member or a member of a structure in correct adjustment and position preparatory to fully welding. Tack welds may be used to restrain welded parts against deformation and distortion resulting from expansion of the metal by atmospheric and welding temperatures.

**Tail Lock.** See SHEAR LOCK.

**Tail Pit.** See COUNTERWEIGHT WELL.

**Tail Water.** Water ponded below the outlet of a culvert, pipe, or bridge waterway, thereby reducing the amount of flow through the waterway. Tailwater is expressed in terms of its depth. See also HEADWATER.

**Temporary Bridge.** A structure built for emergency or interim use to replace a previously existing bridge demolished or rendered unserviceable by flood, fire, wind or other untoward occurrence, or instead, to supply bridge service required for a relatively short period.

**Tendon.** A prestressing cable or strand.

**Tension.** An axial force or stress caused by equal and opposite forces pulling at the ends of the members.

**Throat.** Of a fillet weld. The dimension normal to the sloping face of a fillet weld between the heel of the weld and the sloping faces.

**Through Bridge.** A bridge having its floor elevation more nearly at the elevation of the bottom than at the top portion of the superstructure, thus providing for the passage of traffic between the supporting parts.

**Tide Gate.** See FLOOD GATE.

**Tie Plate.** See STAY PLATE.

**Tie Rod.** (*Tie Bar.*) A rod-like or bar-like member in a truss or other frame functioning to transmit tensile stress.

**Tie Walls.** (*Spandrel Tie Wall.*) One of the walls built at intervals above the arch ring to tie together and reinforce the spandrel walls. See DIAPHRAGM WALL.

Any wall designed to serve as a restraining member to prevent bulging and distortion of two other walls connected thereby.

**Toe of Slope.** The location defined by the intersection of the sloped surface of an approach cut, embankment or causeway or other sloped area with the natural or an artifical ground surface existing at a lower elevation.

**Toe Wall.** (*Footwall.*) A relatively low retaining wall placed near the "toe-of-slope" location of an approach embankment or causeway to produce a fixed termination or to serve as a protection against erosion and scour or, perhaps, to prevent the accumulation of stream debris.

**Toggle Joint.** A mechanical arrangement wherein two members are hinged together, in fact or in effect, at a central location and hinged separately at their opposite ends; their alignment forming an obtuse angle so that a force applied at the common hinge location will produce a thrust acting at the end hinges, laterally to the alignment or direction of the original force.

**Tolerance.** (*Margin.*) A range or variation in physical or chemical properties specified or otherwise determined as permissible for the acceptance and use of construction materials.

**Tower.** 1. A three dimension substructure framework in a viaduct type structure having the vertical bents at its ends joined longitudinally by struts and braces thus rendering the assemblage so formed effective in resisting forces acting longitudinally upon the structure. 2. A four-sided frame supporting the ends of two spans or instead one complete span (tower span) and the ends of two adjacent spans of a viaduct; having its column members strutted and braced in tiers and the planes of either two or four sides battered. 3. A pier or a frame serving to support the cables or chains of a suspension type bridge at the end of a span. 4. A frame functioning as an end support, guide frame and counterweight support for a vertical lift span during an operating cycle.

**Track Girder.** See SEGMENTAL GIRDER.

**Track Plate.** The plate, toothed or plain, upon which the segmental girder of a rolling lift span rolls.

**Track Segment.** One of the assemblage pieces of the circular track supporting the balance wheels of a center bearing swing span or the drum bearing wheels of a drum or combined center and drum bearing span.

**Transition Length.** The tangent length within which the change from a normal to a superelevated roadway cross section is developed.

**Transverse Bracing.** (*Transverse System.*) The bracing assemblage engaging the columns of trestle and viaduct bents and towers in perpendicular or slightly inclined planes and in the horizontal or nearly horizontal planes of their sash braces to function in resisting the transverse forces resulting from wind, lateral vibration and traffic movements tending to produce lateral movement and deformation of the columns united thereby. See BRACING.

**Transverse Girder.** See CROSS GIRDER.

**Travel Way.** See ROADWAY.

**Tread Plates.** (*Roller Tread.*) The plates attached upon the bottom flange of the drum girder; shaped to form a circular surface taking a uniform even bearing upon the drum rollers and thereby transferring to them the live and dead loads of the superimposed structure. The assemblage of tread plates is sometimes described as the "Upper Track."

**Tremie.** A long trunk or pipe used to place concrete under water. A tremie usually has a hopper at its upper end.

The concrete placed under water by use of a tremie is often called tremie concrete. In placing tremie concrete, it is important that the mouth of the tremie be kept immersed within the mass of concrete already deposited to prevent the water from mixing with the concrete, thereby weakening or destroying it.

**Trestle.** A bridge structure consisting of beam, girder or truss spans supported upon bents. The bents may be of the piled or of the frame type, composed of timber, reinforced concrete or metal. When of framed timbers, metal or reinforced concrete they may involve two or more tiers in their construction. Trestle structures are designated as "wooden," "frame," or "framed," "metal," "concrete," "wooden pile," "concrete pile," etc., depending upon or corresponding to the material and characteristics of their principal members.

**Trailing Wheel.** See BALANCE WHEEL.

**Triangular Truss.** See WARREN TRUSS.

**Trunnion.** As applied to a bascule bridge. The assemblage consisting essentially of a pin fitted into a supporting bearing and forming a hinge or axle upon which the movable span swings during an opening-closing cycle.

**Trunnion Girder.** The girder supporting the trunnions on a bascule bridge.

**Truss.** A jointed structure having an open built web construction so arranged that the frame is divided into a series of triangular figures with its component straight members primarily stressed axially only. The triangle is the truss element and each type of truss used in bridge construction is an assemblage of triangles. The connecting pins are assumed to be frictionless.

**Truss Bridge.** A bridge having a truss for a superstructure: The ordinary single span rests upon two supports, one at each end, which may be abutments, piers, bents or towers, or combinations thereof. The superstructure span may be divided into three parts, viz.: (1) the trusses, (2) the floor system and (3) the bracing.

**Truss Panel.** See PANEL.

**Trussed Beam.** A beam reinforced by one or more rods upon its tension side attached at or near its ends and passing beneath a support at the midlength of the span producing in effect an inverted King post truss. The support, if a wooden block, is commonly termed a "saddle block" but, if a cast iron or structural steel member it is termed a "stanchion."

**Tubular Truss.** A truss whose chords and struts are composed of pipes or cylindrical tubes.

**Tudor Arch.** See GOTHIC ARCH.

**Turnbuckle.** A device used to connect the elements of adjustable rod and bar members. It consists of a forging having nut-like end portions right and left hand threaded and integrally connected by two bars upon its opposite sides thus providing an intervening open space through which a lever may be inserted to adjust the tension in the member.

**Turning Pinion and Rack.** The pinion to which the power to operate a swing span is applied and the circular rack fixed upon the pivot pier upon which the pinion travels to produce its rotation movement. When a swing span requires a very considerable amount of power to operate it, two operating pinions located at opposite sides of the circular rack or nearly so are commonly used to distribute the operating force upon the rack and its anchorage.

## U

**U–Bolt.** A bar, either round or square, bent in the shape of the letter "U" and fitted with threads and nuts at its ends.

**Underpass.** See OVERPASS.

**Uplift.** A negative reaction or a force tending to lift a beam, truss, pile, or any other bridge element upwards.

## V

**Vertical-Lift Bridge.** See MOVABLE BRIDGE.

**Viaduct.** A bridge structure consisting of beam, girder, truss, or arch span supported upon abutments with towers or alternate towers and bents or with a series of piers (cylindrical, dumbbell, rectangular or other types), or with any combination of these types of supporting parts.

In general, a viaduct is regarded as having greater height than a trestle. However, this notion is inconsistent with bridge engineering practice. A viaduct may be in all respects like a multiple span bridge.

**Vierendeel Truss.** A rigid frame consisting essentially of an assemblage of rectangles and trapezoids with no diagonal members. Its service in a bridge is the same as that assigned to a plate girder or a truss.

**Voided Unit.** A precast concrete deck unit containing cylindrical voids to reduce dead load.

**Voussoir.** (*Ring Stone.*) One of the truncated wedge shaped stones composing a ring course in a stone arch. The facing or head voussoirs are those placed at the terminations of a ring course.

## W

**Wale.** (*Wale-Piece, Waler.*) A wooden or metal piece or an assemblage of pieces placed either inside or outside, or both inside and outside, the wall portion of a crib, cofferdam or similar structure, usually in a horizontal position to maintain its shape and increase its rigidity, stability, and strength. An assemblage of wale pieces is termed a "waling," or "strake o' wail."

**Warren Truss.** (*Triangular Truss.*) A parallel chord truss developed for use in metal bridge structures, wherein the web system is usually formed by a single triangulation of members at an angle to each other. There are no counters but web members near the center of a span may be subject to stress reversals and are to be designed accordingly. Verticals may or may not be used.

**Washer.** A small metal disc having a hole in its center to engage a bolt or a rivet. It may be used beneath the nut or the head of a bolt or as a separator between elements of a member or the members of a structure.

**Water Table.** The upper limit or elevation of ground water saturating a portion of a soil mass.

**Waterway.** The available width for the passage of stream, tidal or other water beneath a bridge, if unobstructed by natural formations or by artificial constructions beneath or closely adjacent to the structure. For a multiple span bridge the available width is the total of the unobstructed waterway lengths of the spans. See CLEAR SPAN.

**Wearing Surface.** (*Wearing Course.*) The surface portion of a roadway area which is in direct contact with the means of transport and is, therefore, primarily subject to the abrading, crushing or other disintegrating effect produced by hammering, rolling, sliding or other physical action tending to induce attrition thereof.

A topmost layer or course of material applied upon a roadway to receive the traffic service loads and to resist the abrading, crushing or other distintegrating action resulting therefrom.

**Web.** The portion of a beam, girder or truss, located between and connected to the flanges or the chords. It serves mainly to resist shear stresses. The stem of a dumbbell or solid wall type pier.

**Web Members.** The intermediate members of a truss extending, in general, from chord to chord but not including the end posts. Inclined web members are termed diagonals. A "tie" is a diagonal in tension while a brace or strut is a diagonal in compression. A vertical web member in compression is commonly designated a post, while one in tension due entirely to the external forces applied at its lower end, is designated a hanger. The joint formed by the intersection of an inclined end post with the top chord is commonly designated the hip joint or "the hip" end and the vertical tension member engaging the hip joint is commonly known as the hip vertical or the first panel hanger.

**Web Plate.** The plate forming the web element of a plate girder, built-up beam or column.

**Wedge and Pedestals.** An adjustable bearing device or assemblage consisting of a wedge operating between an upper and a lower bearing block or pedestal, and when installed at each outermost end of the girders or the trusses of a swing span, functioning to lift them to an extent that their camber or "droop" will be removed and the arms rendered free to act as simple spans. Furthermore, when installed beneath the loading girder of a center bearing swing span they serve to relieve the pivot bearing from all or nearly all live load and to stabilize the center portion of the span. When the wedges are withdrawn and the end latching device released, the span is free to be moved to an "open" position.

Lifting devices of the wedge and pedestal type may be used under the loading girder of a center bearing swing span in conjunction with rocker and eccentric, link and roller, or other end lifting devices at the ends of the span.

However, some swing spans of short length and placed in rather unimportant locations are designed to support both dead and live loads upon the center pivot and the ends of span are indequately lifted with the result that they "end hammer" upon their pedestals.

**Wedge Stroke.** The theoretical travel distance a wedge must move upon its pedestal to lift the end of the arm of a swing span a distance equal to the vertical camber or "droop" of the arm due to elastic deformation minus the portion assumed to be provided in the field erection operation.

The actual elastic deformation of the arms of a given swing span may vary considerably from the theoretical due probably to temperature variations during the periods in which fabrication and erection are in progress, or to variation in the friction developed between the elements combined to form joints and to other incidental irregularities.

**Weep Hole.** (*Weep Pipe.*) An open hole or an embedded pipe in a masonry retaining wall, abutment, arch or other portion of a masonry structure to provide means of drainage for the embankment, causeway, spandrel backfill or retained soil wherein water may accumulate.

**Weld.** The process of uniting portions of one or more pieces, the elements of a member, or the members of a structure in an intimate and permanent position or status by (1) the application of pressure induced by the blow of a hammer or by a pressure machine, the portions to be united having been previously heated to a so-called welding temperature and the junction areas cleaned and purified by the application of fluxing material, or by (2) the use of a high temperature flame to preheat the metal adjacent to the weld location and when it has attained a molten temperature to add molten weld metal, in conjunction with fluxing material, in sufficient quantity to produce a fully filled joint when cooled or by (3) the use of the electric arc to obtain a molten temperature in the metal closely adjacent to the weld location and to supply in the arc stream molten filler metal and fluxing material requisite to produce by coalescence of the structure and electrode metals a fully filled joint.

The joint produced by the application of a welding process.

**Weld Layer.** A single thickness of weld metal composed of beads (runs) laid in contact to form a pad weld or a portion of a weld made up of superimposed beads.

**Weld Metal.** The fused filler metal which is added to the fused structure metal to produce by coalescence and interdiffusion a welded joint or a weld layer.

**Weld Penetration.** The depth beneath the original surface, to which the structure metal has been fused in the making of a fusion weld. See PENETRATION.

**Weld Sequence.** The order of succession required for making the welds of a built-up piece or the joints of a structure to avoid, so far as practicable, the residual stresses producing or tending to produce individual joint distortions and deformations of the structure or its members.

**Welded Bridge.** (*Welded Structure.*) A structure wherein the metal elements composing its members and the joints whereby these members are combined into the structure frame, are united by welds.

**Welded Joint.** A joint in which the assembled elements and members are united through fusion of metal. The design of a welded joint contemplates a proper distribution of the welds to develop its various parts with relation to the stresses and the purpose which each must serve, due consideration being given to factors productive of secondary stresses through weld shrinkage, warping and other conditions attending weld fabrication.

**Wheel Base.** A term applied to the axle spacing or lengths of vehicles. When applied to automobiles and trucks having wheel concentrations at the ends of the front and rear axles it is the length center to center of axles or the longitudinal dimension center to center of front and rear wheels.

**Wheel Concentration.** (*Wheel Load.*) The load carried by and transmitted to the supporting structure by one wheel. This concentration may involve the wheel of a traffic vehicle, a movable bridge, or other motive equipment or device. See AXLE LOAD.

**Wheel Guard.** (*Filloe Guard.*) A timber piece placed longitudinally along the side limit of the roadway to guide the movements of vehicle wheels and safeguard the bridge trusses, railings and other constructions existing outside the roadway limit from collision with vehicles and their loads.

**Whiteway Lighting.** The lighting provided for nighttime illumination along a road or bridge, as distinguished from sign lighting or colored regulatory and warning lights.

**Wide Flange.** (*Carnegie Beam.*) A rolled member having an H-shaped cross section, differentiated from an I-beam in that the flanges are wider and the web thinner.

**Wind Bracing.** The bracing systems in girder and truss spans and in towers and bents which function to resist the stresses induced by wind forces.

**Wing Wall.** The retaining wall extension of an abutment intended to restrain and hold in place the side slope material of an approach causeway or embankment. When flared at an angle with the breast wall it serves also to deflect stream water and floating debris into the waterway of the bridge and thus protects the approach embankment against erosion. The general forms of wing walls are:

(1) Straight—in continuation of the breast wall of the abutment.

(2) U-type—placed parallel to the alignment of the approach roadway.

(3) Flared—forming an angle with the alignment of the abutment breast wall by receding therefrom.

(4) Curved—forming either a convex or concave arc flaring from the alignment of the abutment breast wall.

The footing of a full abutment height wing wall is usually a continuation of the base portion of the breast wall but may be stepped to a higher or lower elevation to obtain acceptable foundation conditions.

A stub type of straight wing wall is sometimes used in connection with a pier-like or bent-like abutment placed within the end of an embankment. This type, commonly known as "elephant ear" or as "butterfly wing" serves to retain the top portion of the embankment from about the elevation of the bridge seat upward to the roadway elevation. The top surface is battered to conform with the embankment side slope.

**Working Stress.** See STRESS.

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