Ontario Structure Inspection Manual (OSIM)

Ontario

Ministry
of
Transportation

POLICY, PLANNING & STANDARDS DIVISION
ENGINEERING STANDARDS BRANCH
BRIDGE OFFICE
October, 2000

To all users of the: ONTARIO STRUCTURE INSPECTION MANUAL (OSIM)

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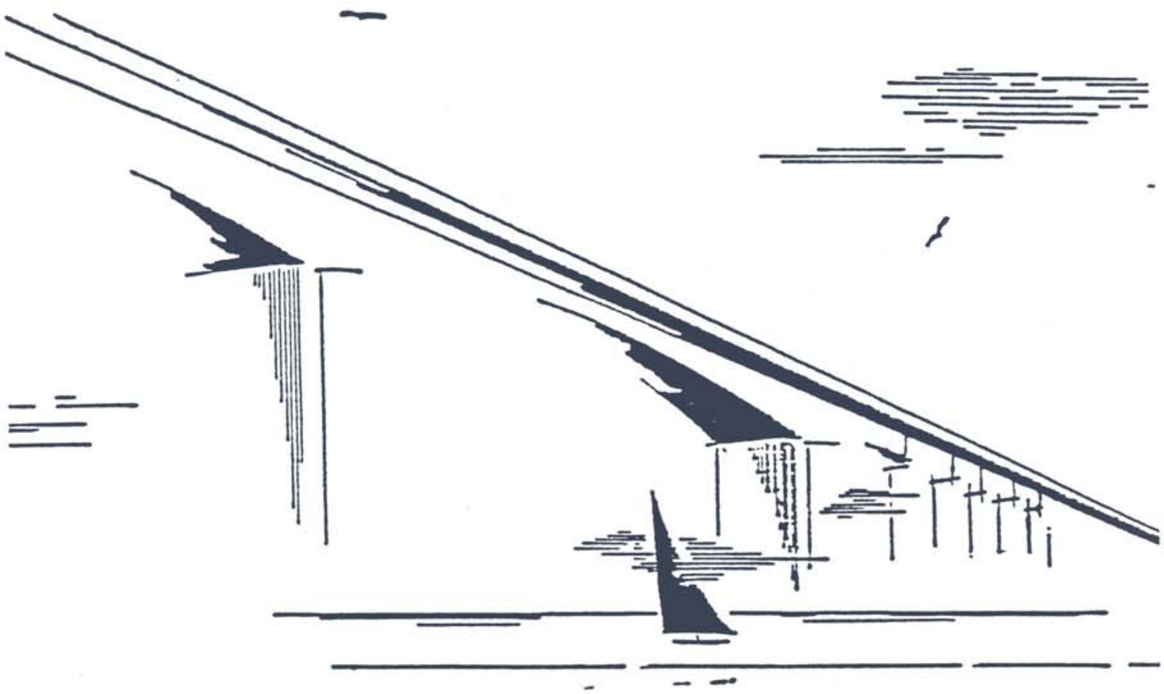

ONTARIO

STRUCTURE INSPECTION MANUAL

OSIM

C O N T E N T S

PREFACE

The Ontario Structure Inspection Manual has been used for bridge inspections in Ontario since 1985. This version of the manual has undergone many modifications. It can be considered an “interim” version since it is recognized that when a new process such as this one is introduced, comments and questions are usually generated. All comments and questions will be recorded and if necessary, a revision to this manual will be issued.

A new “severity and extent” philosophy has been adopted in order to simplify the process of using inspection information to estimate bridge rehabilitation needs and costs. The inspection process is quite similar to the old process except for changes in the way that inspection data is recorded. Material defects of various bridge components, as defined in Section 2, Part 1 of this manual are still valid. The new approach requires that more quantitative data be collected and recorded on the Condition State of bridge elements. Part 1 of the manual also describes the various components of a bridge. These components are grouped into convenient “Elements” for inspection purposes as described in Part 2. Although, primary, secondary and auxiliary components are described in Part 1, for inspection purposes, no distinction is made between these types of components.

The previous Material Condition Rating Tables in Part 2 of the manual have been replaced with Condition State Tables. Four Condition States have been defined for bridge elements, namely, Excellent, Good, Fair and Poor. The condition of bridge elements is defined to be in any one or more of these Condition States. At any given time, areas within a bridge element may be in different Condition States, or the whole of the element may be in the same Condition State. For each bridge element, the inspector assesses and records the amount (area, length or unit as appropriate) of the element in each of the four Condition States. This assessment is based predominately on visual observations, however, some non-destructive testing, such as hammer tapping of concrete for delamination, will be required to determine or verify areas in poor condition. Where an area in poor condition is noted, the area is to be delineated and measured.

The previous Performance Condition Rating Tables in Part 2 have been deleted. The new inspection method requires suspected Performance Deficiencies to be identified for each bridge element. Performance deficiencies are chosen from a standard list and are used to flag areas that require the inspector to take some follow-up action subsequent to the inspection. The inspector should also identify maintenance needs. A standard list of maintenance needs has been created.

Modifications to the manual include:

Part 1 - Technical Information (Section 1 has been completely re-written)

- Ministry of Transportation procedural guidelines have been deleted in an effort to make the manual more generic
- Minor wording changes have been made to the description of some of the material defects in Section 2

Part 2 - Detailed Visual Inspections (This Part has been completely re-written)

- Material Condition Rating (MCR)Tables have been deleted and Condition State Tables have been added

- Performance Condition Rating (PCR) Tables have been deleted and a Suspected Performance Deficiency Tables have been added
- Element lists have been added for each bridge type
- Quantity calculation tables have been added
- Maintenance Needs Tables have been added
- Old inspection forms have been deleted and new forms have been added
- Photograph descriptions have changed to reflect Condition State language

Part 3 - Additional Investigations (This Part has been completely re-written)

- Reference to load posting has been deleted and covered in Suspected Performance Deficiency Section
- Wording changes have been made for condition surveys and other investigations

Part 4 - Material Condition Surveys

- No change

Part 5 - Underwater Inspections

- No change

INTRODUCTION

The need for mobility requires that Ontario's highway system be kept in good repair. Structures are a vital part of this system. The efficiency of the system is impaired and the public inconvenienced if a structure fails or its load-carrying capacity is reduced for any reason. To avoid such failings, an effective structure management system is required.

An essential component of structure management system involves the systematic inspection of the structures on the highway network.

This manual sets standards for detailed visual inspection and condition rating of structures and their components. It provides a uniform inspection approach for all structures in Ontario.

Part 1 gives general details of inspection procedures, bridge components, material defects and performance defects

Part 2 sets out requirements for detailed visual inspection and condition rating of structures and their components.

Part 3 provides guidelines for the need to carry out further investigations and special studies.

Part 4 describes various types of procedures and equipment for the non-destructive testing of materials and provides guidelines and requirements for carrying out these tests.

Part 5 provides guidelines and requirements for underwater investigations.

GENERAL DEFINITIONS

Abutment	-	A substructure unit which supports the end of the structure and retains the approach fill.
Auxiliary Components	-	Any component which does not share in the load carrying capacity of the structure.
Bridge	-	A structure which provides a roadway or walkway for the passage of vehicles across an obstruction, gap or facility and which is greater than 3 m in span.
Chord	-	The upper and lower main longitudinal component in trusses or arches extending the full length of the structure.
Coating	-	The generic term for paint, lacquer, enamel, sealers, galvanizing, metallizing, etc.
Concrete Deck Condition Survey	-	A detailed inspection of a concrete deck in accordance with The Structure Rehabilitation Manual.
Culvert	-	Any bridge that is embedded in fill and is used to convey water, pedestrians or animals through it.
Defect	-	An identifiable, unwanted condition that was not part of the original intent of design.
Detailed Visual Inspection	-	An element by element visual assessment of material defects, performance deficiencies and maintenance needs of a structure.
Deterioration	-	A defect that has occurred over a period of time.
Diagonals	-	Component which spans between the top and bottom chord of a truss or arch in a diagonal direction.
Distress	-	A defect produced by loading.
Elements	-	The individual parts of a structure defined for inspection purposes. Several bridge components may be grouped together to form one bridge element for inspection purposes
Engineer	-	A member or licensee of the Professional Engineers of Ontario.
Environment	-	An element's exposure to salt spray: Benign - Not exposed e.g. River Pier Moderate - Exposed but element protected e.g. Asphalt covered and waterproofed deck Severe - Exposed and element not protected e.g. Exposed concrete deck, Barrier Wall
Evaluation	-	The determination of the load carrying capacity of structures in accordance with the requirements of the Ontario Highway Bridge

Design Code or the Canadian Highway Bridge Design Code, when implemented.

Floor Beam	-	Transverse beams that span between trusses, arches or girders and transmit loads from the deck and stringers to the trusses, arches or girders.
Highway	-	A common and public thoroughfare including street, avenue, parkway, driveway, square, place, bridge, designed and intended for, or used by, the general public for passage of vehicles, pedestrians or animals.
Lateral Bracing	-	Bracing which lies in the plane of the top or bottom chords or flanges and provides lateral stability and resistance to wind loads.
Maintenance	-	Any action which is aimed at preventing the development of defects or preventing deterioration of a structure or its components.
Masonry	-	Structure made up of natural stones separated by mortar joints, usually in uniform courses. Masonry in existing structures is usually in retaining walls, abutments, piers or arches.
Masonry Ashlar	-	Stone worked to a square shape or cut square with uniform coursing height and vertical joints staggered. The stone has a minimum course height of 200 mm set in joints with an average thickness of 10 mm or less.
Masonry Squared Stone	-	Stone in natural bed thicknesses or roughly squared stones with course height less than 200 mm and joints greater than 10 mm but not over 20 mm.
Masonry Rubble	-	Stone masonry constructed with rough field stones or only roughly squared stones set in mortar joints with average thickness greater than 20 mm. Also any squared stone masonry in which the joints are greater than 20 mm, but less than 30 mm in thickness.
Minister	-	The Minister of the Ministry of Transportation of Ontario or his nominee.
Ministry	-	The Ministry of Transportation of Ontario
Owner	-	A person having jurisdiction and control over the bridge.
Person	-	An individual, board, commission, partnership or corporation, including a municipal corporation, and employees, agents, successors and assigns of any of them.
Plans	-	All drawings, descriptions and specifications, being parts of the contract, and all drawings and descriptions produced by the constructor for the erection of a bridge or structure, and all revisions thereto.
Portal Bracing	-	Overhead bracing at the ends of a through truss or arch and provides lateral stability and shear transfer between trusses.
Primary Components	-	The main load carrying components of the structure.

Rehabilitation	-	Any modification, alteration, retrofitting or improvement to a structure sub-system or to the structure which is aimed at correcting existing defects or deficiencies.
Repair	-	Any modification, alteration, retrofitting or improvement to a component of the structure which is aimed at correcting existing defects or deficiencies.
Retaining Wall	-	Any structure that holds back fill and is not connected to a bridge.
Secondary Components	-	Any component which helps to distribute loads to primary components, or carries wind loads, or stabilizes primary components.
Sign Support	-	A metal, concrete or timber structure, including supporting brackets, service walks and mechanical devices where present, which support a luminaire, sign or traffic signal and which span or extend over a highway.
Span	-	The horizontal distance between adjacent supports of the superstructure of a bridge, or the longest horizontal dimension of the cross-section of a culvert or tunnel taken perpendicular to the walls.
Stringers	-	Stringers span between floor beams and provide the support for the deck above.
Structure	-	Bridge, culvert, tunnel, retaining wall or sign support.
Suspected Performance Deficiency	-	A Suspected Performance Deficiency should be recorded during an inspection, if an element's ability to perform its intended function is in question, and one or more performance defects exist.
Sway Bracing	-	Vertical bracing spanning between through trusses or arches, or outside of half-through trusses or arches and providing lateral stability and shear transfer between the trusses or arches.
Tunnel	-	Any bridge that is constructed through existing ground, and is used to convey highway or railway traffic through it.
Verticals	-	Components which span between the top and bottom chords of a truss or arch in the vertical direction.

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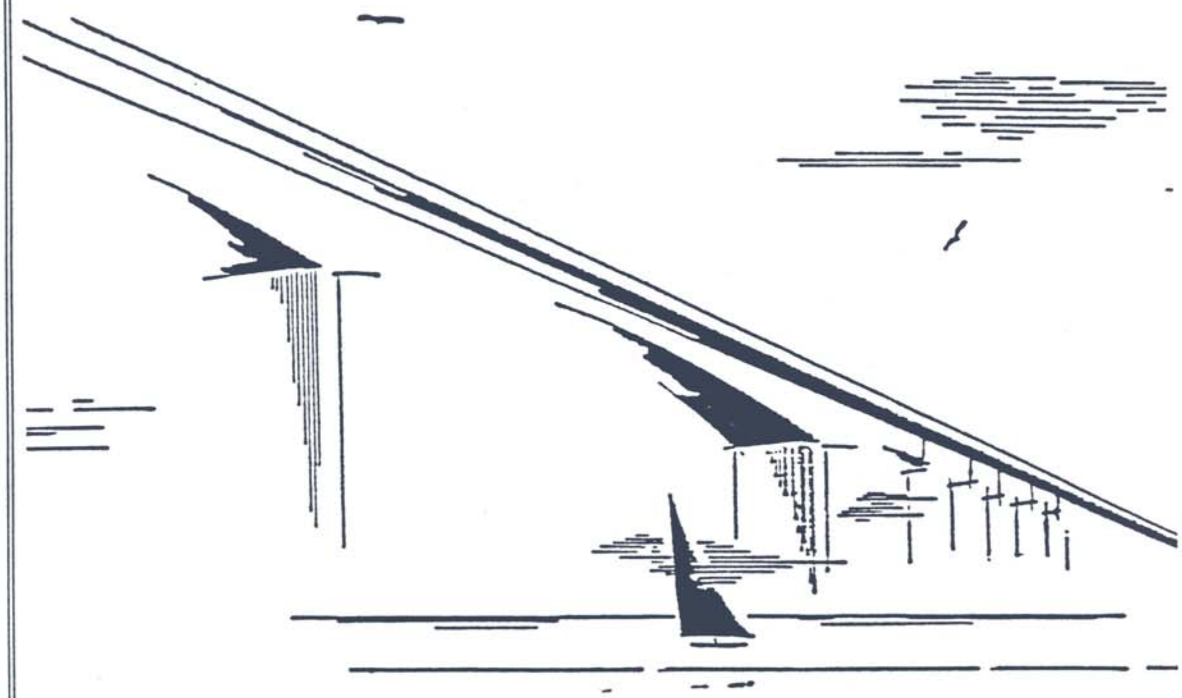


ONTARIO

STRUCTURE INSPECTION MANUAL

Part 1 – Technical Information

PART 1 - TECHNICAL INFORMATION

C O N T E N T S

SECTION 1 - STRUCTURAL INSPECTIONS

Contents

1.1 STRUCTURAL INSPECTIONS

This section sets out the goals and objectives of structural inspections. It identifies the types of inspections and the types of structures to which this manual applies.

1.2 GOAL AND OBJECTIVES OF STRUCTURAL INSPECTIONS

1.2.1 Goal

The goal of structural inspections is to ensure, within an economic framework, an acceptable standard for structures in terms of public safety, comfort and convenience.

1.2.2 Objectives

The main objectives of Structural Inspections are:

- to protect and prolong the useful life of structures;
- to identify maintenance, repair and rehabilitation needs of structures; and,
- to provide a basis for a structure management system for the planning and funding of the maintenance and rehabilitation of structures.

1.3 INSPECTIONS OF STRUCTURES

To achieve the goal and objectives of structural inspections, detailed visual inspections of bridges should be performed regularly. A detailed visual inspection is an element-by-element "close-up" visual assessment of material defects, performance deficiencies and maintenance needs of a structure. "Close-up is defined as "a distance close enough to determine the condition of the element". In many cases, the inspection should be conducted within arms length of the element, possibly involving tapping with a hammer or making measurements by hand. Appropriate special equipment (Bridgemaster, bucket truck, ladders, etc) should be used to facilitate this assessment. It is expected that in order to adequately assess the condition of all elements, the inspector should plan to spend at least 2 to 3 hours at a typical bridge site. For large bridges, this time will increase.

In addition to detailed inspections, routine inspections by maintenance crews are essential, and should be performed regularly to identify sudden changes in bridge condition. This manual describes the procedures for carrying out detailed visual inspections only.

1.3.1 Frequency of Detailed Visual Inspections

The following structures shall be inspected every two years (Biennially):

- **All bridges, culverts and tunnels with spans over 3 metres**
- **All retaining walls**
- **All movable bridges**

For culverts with 3 to 6 metre spans and retaining walls, the inspection interval can be increased to four years if the culvert or retaining wall is in good condition and the engineer believes that the culvert or retaining wall condition will not change significantly before the next inspection.

It is recognized that the level of effort involved in performing a detailed visual inspection will vary depending on structure type and age. For example, if a bridge is less than 5 years old, it is unlikely that there will be much change in bridge condition from one inspection to the next. Consequently, the inspection time may be relatively short. However, the inspector must be satisfied that everything possible has been done to determine the condition of the various bridge elements.

It is also recognized that one of the purposes of regular inspections is to identify changes in bridge condition. If taken in this context, the importance of having a qualified inspector assess the condition of structure every two years, cannot be over emphasized.

The frequency of inspections given above, applies to all structures in good repair. The maximum inspection interval and the level of inspection may however vary for certain structures. Some structures may have to be inspected more frequently as directed the Engineer. Such action can be justified based upon the type of structure, construction details, existing problems or restrictions, and material and performance condition history. Structures or components requiring more frequent inspection include:

- structures with a high proportion of elements in the Poor Condition State;
- structures with load limits on them
- new types of structures or details with no previous performance history;
- structures with load or clearance restrictions;
- single load path structures
- structures with fatigue prone details;
- structures with fracture critical components;
- pins and hangers in arch structures;
- pins in suspended spans and pinned arches.

Often, more detailed investigations and non-destructive testing techniques are required to identify defects for the above cases. The inspector should recommend that these specialized investigations be performed regularly, where warranted.

Inspection procedures detailed in this manual do not apply to the mechanical or electrical parts of movable bridges. The inspection of overhead sign support structures is covered in the Ontario Sign Support Inspection Guidelines. Bridge mounted sign supports and banner mounting hardware should also be inspected in accordance with the Ontario Sign Support Inspection Guidelines. For ease of access, the inspector should plan to inspect these components when on site for the biennial bridge inspection.

1.3.2 Emergency Inspections

An emergency situation exists when a structural component contributing to overall stability of the structure has failed, or is in imminent danger of failure or public safety is in any way at risk. In such cases, a detailed visual inspection should be carried out immediately. Typical problems that may cause an emergency situation to develop are:

- Accident or vehicle collision with a structure
- Spring run-off or major flooding
- An earthquake
- Cracks in steel components
- Loose concrete in an overhead structure

1.3.3 Specialized Investigations

If during a detailed visual inspection, the inspector feels that more detailed information is needed, specialized inspections can be requested. Some of these investigations are:

- Detailed Deck Condition Survey
- Non-destructive Delamination Survey of Asphalt Covered Decks
- Substructure Condition Survey
- Detailed Coating Condition Survey
- Underwater investigation
- Fatigue investigation
- Seismic investigation
- Structure evaluation

Information on these inspections is contained in Part 3 of this manual.

SECTION 2 - MATERIAL DEFECTS

Contents

2.1 MATERIAL DEFECTS

This section describes the defects that are normally found in concrete, steel, wood, masonry, aluminum, asphalt pavements and coatings. Each defect is briefly described and the causes producing it are identified. Severity levels, wherever possible, are established.

2.2 CONCRETE

Concrete is used in structures as plain concrete, such as in tremie and mass concrete; or, it is combined with conventional steel reinforcement as reinforced concrete, or with prestressing steel reinforcement as prestressed concrete.

Defects in concrete can often be related to the lack of durability of the concrete, resulting from the composition of the concrete, poor placement practices, poor Quality Control or the aggressive environment in which it is placed.

The following defects commonly occurring in concrete are described:

- Scaling
- Disintegration
- Erosion
- Corrosion of Reinforcement
- Delamination
- Spalling
- Cracking
- Alkali-Aggregate Reaction
- Surface Defects

2.2.1 SCALING

Scaling is the local flaking, or loss of the surface portion of concrete or mortar as a result of the freeze-thaw deterioration of concrete. Scaling is common in non air-entrained concrete, but can also occur in air-entrained concrete in the fully saturated condition. Scaling is prone to occur in poorly finished or overworked concrete where too many fines and not enough entrained air is found near the surface. Scaling of concrete is shown in Figure 2.2.1.

Severity

Light	- Loss of surface mortar to a depth of up to 5 mm without exposure of coarse aggregate;
Medium	- Loss of surface mortar to a depth of 6 to 10 mm with exposure of some coarse aggregates;
Severe	- Loss of surface mortar to a depth of 11 mm to 20 mm with aggregate particles standing out from the concrete and a few completely lost.
Very Severe	- Loss of surface mortar and aggregate particles to a depth greater than 20 mm.

2.2.2 DISINTEGRATION

Disintegration is the physical deterioration or breaking down of the concrete into small fragments or particles. The deterioration usually starts in the form of scaling and, if allowed to progress beyond the level of very severe scaling is considered as disintegration. Disintegration may be caused by de-icing chemicals, sulphates, chlorides or by frost action. Disintegration of the concrete is illustrated in Figure 2.2.2.

Severity

Light	- Loss of section up to 25 mm in depth with some loss of coarse aggregate;
Medium	- Loss of section between 25 mm and 50 mm deep with considerable loss of coarse aggregate and exposure of reinforcement;
Severe	- Loss of section between 50 mm and 100 mm deep with substantial loss of coarse aggregate and exposure of reinforcement over a large area.
Very Severe	- Loss of section in excess of 100 mm deep and extending over a large area.

2.2.3 EROSION

Erosion is the deterioration of concrete brought about by water-borne sand and gravel particles scrubbing against concrete surfaces. Similar, damage may be caused by flowing ice. Erosion is sometimes combined with the chemical action of air and water-borne pollutants which accelerate the breakdown of the concrete.

Erosion is generally an indication that the concrete is not durable enough for the environment in which it has been placed. Severe erosion of a concrete footing is shown in Figure 2.2.3.

Severity

Light - Loss of section up to 25 mm in depth with some loss of coarse aggregate;

Medium - Loss of section between 25 mm and 50 mm deep with considerable loss of coarse aggregate and exposure of reinforcement;

Severe - Loss of section between 50 mm and 100 mm deep with substantial loss of coarse aggregate and exposure of reinforcement over a large area.

Very Severe - Loss of section is in excess of 100 mm deep and extending over a large area.

2.2.4 CORROSION OF REINFORCEMENT

Corrosion is the deterioration of reinforcement by electrolysis. The alkali content in concrete protects the reinforcement from corrosion. However, when chloride ions above a certain concentration are dissolved in water and penetrate through the concrete to the reinforcement this protection breaks down and corrosion starts. In the initial stages, corrosion may appear as a rust-stain on the concrete surface. In the advanced stages, the surface concrete above the reinforcement cracks, delaminates and spalls off exposing heavily rusted reinforcement. This process is illustrated in Figure 2.2.4(a).

Severity

Light - Light rust stain on the concrete surface;

Medium - Exposed reinforcement with uniform light rust.
Loss of reinforcing steel section less than 10%;

Severe - Exposed reinforcement with heavy rusting and localized pitting.
Loss of reinforcing steel section between 10% and 20%;

Very Severe - Exposed reinforcement with very heavy rusting and pitting.
Loss of reinforcing steel section over 20%.

2.2.5 DELAMINATION

Delamination is defined as a discontinuity of the surface concrete which is substantially separated but not completely detached from concrete below or above it. Visibly, it may appear as a solid surface but can be identified as a hollow sound by tapping or chain dragging. Delamination begins with the corrosion of reinforcement and subsequent cracking of the concrete. However, in the case of closely spaced bars, the cracking extends in the plane of the reinforcement parallel to the exterior surface of the concrete. Delamination in a concrete beam is shown in Figure 2.2.5.

Delamination or debonding may also occur in concrete that has been patched or overlaid due to the continued deterioration of the older concrete. This may happen even in the absence of any rusting of reinforcing steel.

Severity

Light	- Delaminated area measuring less than 150 mm in any direction.
Medium	- Delaminated area measuring 150 mm to 300 mm in any direction.
Severe	- Delaminated area measuring 300 mm to 600 mm in any direction.
Very Severe	- Delaminated area measuring more than 600 mm in any direction.

2.2.6 SPALLING

A spall is a fragment, which has been detached from a larger concrete mass.

Spalling is a continuation of the delamination process whereby the actions of external loads, pressure exerted by the corrosion of reinforcement or by the formation of ice in the delaminated area results in the breaking off of the delaminated concrete. The spalled area left behind is characterized by sharp edges. Very severe spalling in a concrete beam and local severe spalling in a concrete deck are illustrated in Figures 2.2.6(a) and 2.2.6(b) respectively.

Vehicular, ice flow or other impact forces on exposed concrete edges, deck joints or construction joints, may also result in the spalling or breaking off of pieces of concrete locally.

Spalling may also be caused by overloading of the concrete in compression. This results in the breaking off of the concrete cover to the depth of the outer layer of reinforcement. Spalling may also occur in areas of localized high compressive load concentrations, such as at structure supports, or at anchorage zones in post-tensioned concrete.

Spalling of patched areas may occur due to continued deterioration of the old concrete and subsequent breaking off of the new patch.

Severity

Light	- Spalled area measuring less than 150 mm in any direction or less than 25 mm in depth.
Medium	- Spalled area measuring between 150 mm to 300 mm in any direction or between 25 mm and 50 mm in depth.
Severe	- Spalled area measuring between 300 mm to 600 mm in any direction or between 50 mm and 100 mm in depth.
Very Severe	- Spalled area measuring more than 600 mm in any direction or greater than 100 mm in depth.

2.2.7 CRACKING

A crack is a linear fracture in concrete which extends partly or completely through the member. Cracks in concrete occur as a result of tensile stresses introduced in the concrete. Tensile stresses are initially carried by the concrete and reinforcement until the level of the tensile stresses exceeds the tensile capacity (modulus of rupture) of the concrete. After this point the concrete cracks and the tensile force is transferred completely to the steel reinforcement. The crack widths and distribution is controlled by the reinforcement in reinforced and prestressed concrete, whereas in plain concrete there is no such control.

The build-up of tensile stresses and, therefore, cracks in concrete may be due to externally applied loads, external restraint forces, internal restraint forces, differential movements and settlements, or corrosion of reinforcement. Externally applied loads generate a system(s) of internal compressive and tensile stresses, in the members and components of the structure, as required to maintain static equilibrium. Cracks resulting from externally applied loads initially appear as hairline cracks and are harmless. However, as the reinforcement is further stressed the initial cracks open up and progressively spread into numerous wider cracks. Figure 2.2.7(a) shows typical flexure, shear, axial and torsional cracks due to applied external load.

External restraint forces are generated if the free movement of the concrete in response to the effects of temperature, creep and shrinkage is prevented from occurring due to restraint at the member supports. The restraint may consist of friction at the bearings, bonding to already hardened concrete, or by attachment to other components of the structure. Cracks resulting from the actions of external restraint forces develop in a similar manner as those due to externally applied loads. Figure 2.2.7(b) shows restraint induced cracking due to an increase in temperature of the top surface of a beam.

Internal restraint forces are caused by the differential expansion or contraction of the exterior surface of concrete relative to the interior mass of the concrete, as in plastic shrinkage. The resulting surface cracks are normally shallow and appear as pattern cracks, checking and D-cracks. Figure 2.2.7(c) shows medium pattern cracking in an abutment wall.

These internal forces may also be caused by carbonation of concrete. The calcium from the concrete reacts with carbonic acid (which occurs when the carbon dioxide in the air combines with moisture) resulting in a volume decrease. This volume decrease occurs only in the outer layer of the concrete, but usually hairline pattern cracks and a surface discolouration result.

Differential movements or settlements result in the redistribution of external reactions and internal forces in the structure. This may in turn result in the introduction of additional tensile stresses and, therefore, cracking in the concrete components of the structure. Movement cracks may be of any orientation and width, ranging from fine cracks above the reinforcement due to formwork settlement, to wide cracks due to foundation or support settlement. Figure 2.2.7(d) shows movement induced cracks.

Corrosion of reinforcement produces cracks as described in 2.2.4. Corrosion related cracks are shown in Figure 2.2.7(e).

Severity

Hairline cracks - less than 0.1 mm wide.

Narrow cracks - 0.1 mm to 0.3 mm wide.

Medium cracks - 0.3 mm to 1.0 mm wide.

Wide cracks - greater than 1.0 mm wide.

2.2.8 ALKALI-AGGREGATE REACTION

Some aggregates react adversely with the alkalis in cement to produce a highly expansive alkali-silica gel. The expansion of the gel and aggregates under moist conditions lead to cracking and deterioration of the concrete. The cracking occurs through the entire mass of the concrete (Reference 1). Alkali aggregate reactions are generally slow by nature, and the results may not be apparent for many years. Once the alkali-aggregate reaction starts, there are no remedial measures to stop or reverse the process of deterioration. The appearance of concrete affected by alkali-aggregate reactions is shown in Figure 2.2.8.

Severity

Light - Hairline pattern cracks, widely spaced, with no visible expansion of the concrete mass.

Medium - Narrow pattern cracks, closely spaced, with visible expansion of the concrete mass.

Severe - Medium to wide pattern cracks, closely spaced, with visible expansion and deterioration of concrete.

Very Severe - Wide pattern cracks, closely spaced, with extensive expansion and deterioration of concrete.

2.2.9 SURFACE DEFECTS

The following surface defects in concrete are described herein:

- Stratification;
- Segregation;
- Cold Joints;
- Deposits - efflorescence, exudation, incrustation, stalactite;
- Honeycombing;
- Pop-outs;
- Abrasion and Wear
- Slippery Surface

Surface defects are not necessarily serious in themselves; however, they are indicative of a potential weakness in the concrete, and their presence should be noted but not classified as to severity, except for honeycombing and pop-outs.

STRATIFICATION is the separation of the concrete components into horizontal layers in over-wetted or over-vibrated concrete. Water, laitance, mortar and coarse aggregates occupy successively lower positions. A layered structure in concrete will also result from the placing of successive batches that differ in appearance.

SEGREGATION is the differential concentration of the components of mixed concrete resulting in non-uniform proportions in the mass. Segregation is caused by concrete falling from a height, with the coarse aggregates settling to the bottom and the fines on top. Another form of segregation occurs where reinforcing bars prevent the uniform flow of concrete between them.

COLD JOINTS are produced if there is a delay between the placement of successive pours of concrete, and if an incomplete bond develops at the joint due to the partial setting of the concrete in the first pour.

DEPOSITS are often left behind where water percolates through the concrete and dissolves or leaches chemicals from it and deposits them on the surface. Deposits may appear as the following:

Efflorescence	-	a deposit of salts, usually white and powdery.
Exudation	-	a liquid or gel-like discharge through pores or cracks in the surface.
Incrustation	-	a hard crust or coating formed on the concrete surface.
Stalactite	-	a downward pointing formation hanging from the concrete surface, usually shaped like an icicle.

HONEYCOMBING is produced due to the improper or incomplete vibration of the concrete which results in voids being left in the concrete where the mortar failed to completely fill the spaces between the coarse aggregate particles. Figure 2.2.9 shows <u>medium</u> honeycombing in the underside of a deck slab.

Severity

Light - Honeycombing to a depth less than 25mm.

Medium- Honeycombing to a depth between 25mm and 50mm.

Severe - Honeycombing to a depth between 50mm and 100mm.

Very Severe - Honeycombing to a depth less than 100mm.

POP-OUTS are shallow, typically conical depressions, resulting from the breaking away of small portions of the concrete surface, due to the expansion of some aggregates or due to frost action. The shattered aggregate particle may be found at the bottom of the depression, with a part of the aggregate still adhering to the pop-out cone.

Severity

Light - Pop-outs leaving holes up to 25 mm in depth.

Medium- Pop-outs leaving holes between 25 mm and 50 mm in depth.

Severe - Pop-outs leaving holes between 50 mm and 100 mm in depth.

Very Severe - Pop-outs leaving holes greater than 100 mm in depth.

ABRASION is the deterioration of concrete brought about by vehicles or snow-plough blades scraping against concrete surfaces, such as, decks, curbs, barrier walls or piers.

WEAR is usually the result of dynamic and/or frictional forces generated by vehicular traffic, coupled with the abrasive influx of sand, dirt and debris. It can also result from the friction of ice or water-borne particles against partly or completely submerged members. The surface of the concrete appears polished.

SLIPPERY CONCRETE SURFACES may result from the polishing of the concrete deck surface by the action of repetitive vehicular traffic.

Severity

There are no severity descriptions given for slippery concrete surfaces as this is a serious and potentially hazardous situation. Where evidence of slippery concrete deck surface is noted the District and Regional Traffic Offices shall be notified.

Figure 2.2.1 Severe Scaling in a Concrete Deck and Curb

Figure 2.2.2 Very Severe Disintegration of Concrete in Exterior Face

Figure 2.2.3 Very Severe Erosion of a Concrete Footing

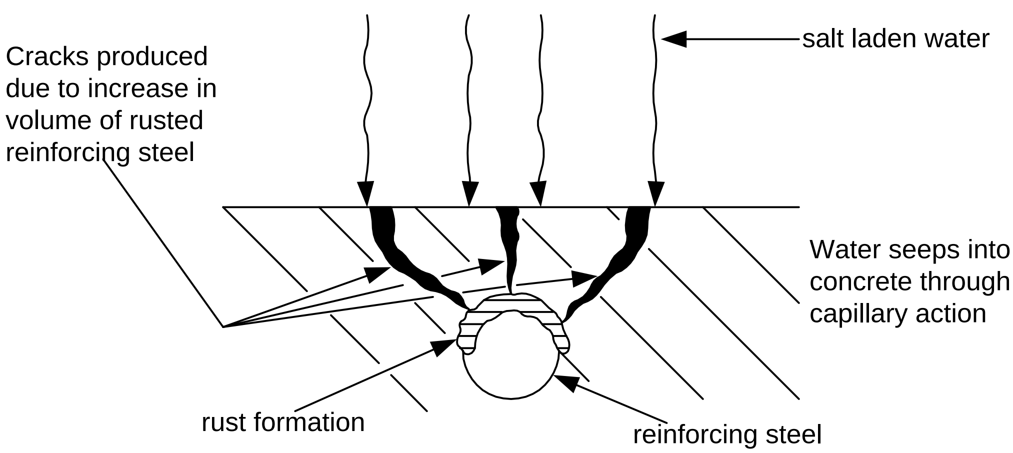


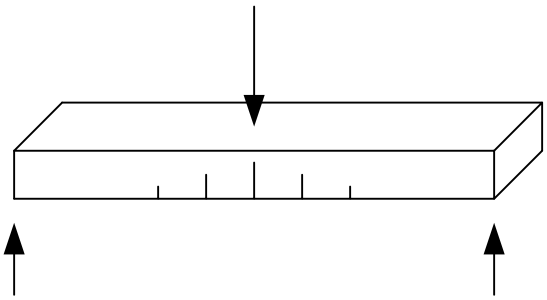
Figure 2.2.4(a) Process Leading to Corrosion of Reinforcement

Figure 2.2.4(b) Light Stains on Concrete Surface
Indicating Corrosion of Reinforcement

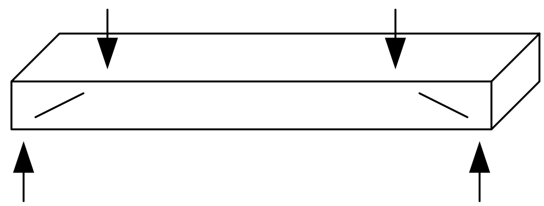
Figure 2.2.5 Very Severe Spalling and Delamination in
Concrete Beams

Figure 2.2.6(a) Very Severe Spalling in a Concrete Pier Cap Due to Corrosion of Reinforcement

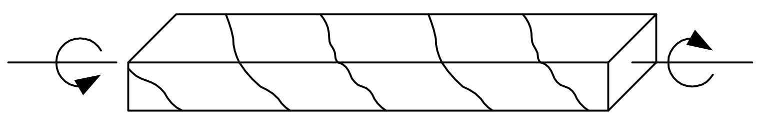
Figure 2.2.6(b) Severe Local Spalling



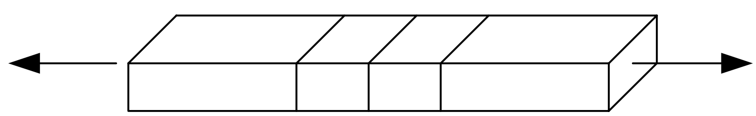
Flexure Cracks



Shear Cracks



Torsion Cracks



Axial Cracks

Figure 2.2.7(a) Applied Loading Cracks

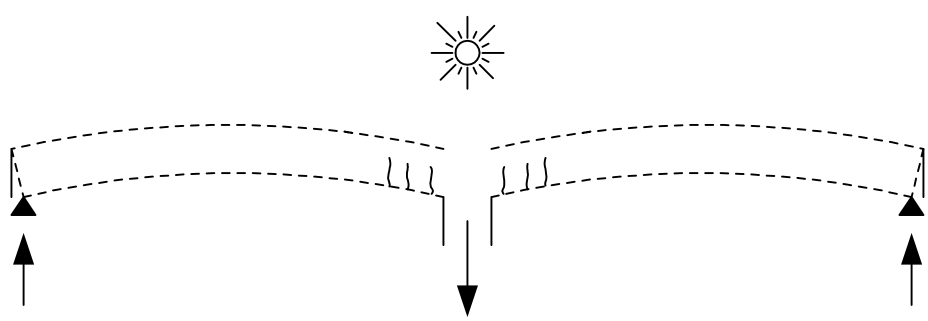


Figure 2.2.7(b) External Restraint Induced Cracks
(due to temperature increase in top surface of beam)

Figure 2.2.7(c) Medium Pattern Cracks in an Abutment

Figure 2.2.7(d) Very Wide Movement Crack in an Abutment

Figure 2.2.7(e) Medium Cracks due to Corrosion of Reinforcement

Figure 2.2.8 Severe Alkali-Aggregate Reaction

Figure 2.2.9 Severe Honeycombing in the Underside of a Deck Slab

2.3 STEEL

The use of steel has progressed from cast iron, wrought iron, rivet steel and plain carbon steel to low alloy atmospheric corrosion resistant steel (weathering steel) and notch tough low temperature steel.

The following defects commonly occurring in steel are described:

- Corrosion;
- Permanent Deformation;
- Cracking;
- Loose Connections.

2.3.1 CORROSION

Corrosion is the deterioration of steel by chemical or electro-chemical reaction resulting from exposure to air, moisture, de-icing salts, industrial fumes and other chemicals and contaminants in the environment in which it is placed. The terms rust and corrosion are used inter-changeably in this sense. Corrosion, or rusting, will only occur if the steel is not protected or if the protective coating wears or breaks off.

Rust on carbon steel is initially fine grained, but as rusting progresses it becomes flaky and delaminates exposing a pitted surface. The process thus continues with progressive loss of section.

Weathering steel, on the other hand, will form a relatively smooth rust layer, called a patina, which protects the underlying metal from further corrosion. However, in less than ideal circumstances, the patina may not form or may be penetrated and delaminated, resulting in progressive corrosion (References 2,3).

For weathering steel to form a tightly adherent patina, the following conditions must be met:

- the steel must be exposed to intermittent wetting and drying cycles;

- corrosive contaminants, especially salt bearing water, must be absent;

- the steel surfaces must be kept clean and free of entrapped dirt, debris and moisture.

In addition to the above, mill scale is often left on weathering steel to "weather off", except where it is removed for appearance; however, if the mill scale is scratched, then the underlying metal may corrode.

Corrosion in steel is illustrated in Figure 2.3.1.

Severity

Light - Loose rust formation and pitting in the paint surface. No noticeable section loss.

Medium - Loose rust formation with scales or flakes forming. Definite areas of rust are noticeable. Up to 10% section loss.

Severe - Stratified rust with pitting of the metal surface. Between 10% to 20% section loss.

Very Severe - Extensive rusting with local perforation or rusting through. In excess of 20% section loss.

2.3.2 PERMANENT DEFORMATIONS

Permanent deformation of steel members can take the form of bending, buckling, twisting or elongation, or any combination of these. Permanent deformations may be caused by overloading, vehicular collision, or inadequate or damaged intermediate lateral supports or bracing. See Figure 2.3.2.

Permanent bending deformations occur in the direction of the applied loads and are usually associated with flexural members; however, vehicular impact may produce permanent deformations in bending in any other member.

Permanent buckling deformations normally occur in a direction perpendicular to the applied load and are usually associated with compression members. Buckling may also produce local permanent deformations of webs and flanges of beams, plate girders or box girders.

Permanent twisting deformations appear as a rotation of the member about its longitudinal axis and are usually the result of eccentric transverse loads on the member.

Permanent axial deformations occur along the length of the member and are normally associated with applied tension loads.

Severity

As permanent deformations may be critical to the integrity of the member and/or structure, no severity ratings are given. However, the location of the deformation in the member, and member in the structure, should be recorded.

Photographs and measurements of the amount and extent of deformation shall be taken and recorded for analysis by an engineer.

2.3.3 CRACKING

CRACK is a linear fracture in the steel. Cracks are mainly produced due to fatigue and can, under certain conditions, lead to a brittle fracture.

BRITTLE FRACTURE is a crack completely through the component that usually occurs without prior warning or plastic deformation. Brittle fracture may result at fatigue prone details after initial fatigue cracking.

FATIGUE PRONE DETAILS are those details that are susceptible to the growth of fatigue cracks. Details in fatigue stress categories E and F, which are most susceptible to fatigue crack growth, are illustrated in references 9 and 10.

FRACTURE CRITICAL COMPONENTS are components which are subject to tensile stresses in a single load path structure and whose failure could lead to collapse of the structure. Any attachment having a length in the direction of tension stress greater than 100 mm. and that is welded to the tension area of a fracture critical component shall also be considered as fracture critical.

The primary factors leading to fatigue cracking are: the number of applied stress cycles, which is a function of the volume of traffic; the magnitude of the stress range, which depends on the applied live load; and the fatigue strength of the connection detail, category A to W, as given in the Ontario Highway Bridge Design Code, reference 10. Cracks caused by fatigue usually occur at points of tensile stress concentrations, at welded attachments or at termination points of welds. Cracks may also be caused or aggravated by overloading, vehicular collision or loss of section resistance due to corrosion. In addition, stress concentrations due to the poor quality of fabricated details and the fracture toughness of materials used are contributing factors. Material fracture toughness will determine the size of crack that can be tolerated before fracture occurs.

Welded details are more prone to cracking than bolted or riveted details. Grinding off the weld reinforcement to be smooth or flush with the joined metal surfaces improves fatigue resistance. Once cracking occurs in a welded connection, it can extend into other components due to a continuous path provided at the welded connection, and possibly lead to a brittle fracture.

Bolted or riveted connections may also develop fatigue cracking, but a crack in one component will generally not pass through into the others. Bolted and riveted connections are also susceptible to cracking or tearing resulting from prying action, and by a build-up of corrosion forces between the parts of the connection.

Cracking which has resulted in a brittle fracture in a diaphragm beam is shown in Figure 2.3.3(a).

Common locations susceptible to cracking are illustrated in Figure 2.3.3(b). As cracks may be concealed by rust, dirt or debris, the suspect surfaces should be cleaned prior to inspection.

Severity

Cracks that are parallel with the direction of stress are usually not very serious; however, those perpendicular to the direction of stress are very serious. In either case, cracks in steel should generally be considered serious, as a parallel crack may for a number of reasons turn into a perpendicular crack. Therefore, no severity description for cracks is given. Any crack should be carefully noted and recorded as to its specific location in the member, and member in the structure. The length, width (if possible) and direction of crack should also be recorded.

2.3.4 CONNECTION DEFICIENCIES

Loose connections can occur in bolted, riveted or clamped connections. The loose condition may be caused by corrosion of the connector, gusset plates or fasteners, cracking or failure of the individual fasteners, excessive vibration, over stressing, or simply a lack of proper tightening during construction.

Loose connections may not always be detectable by visual or hands-on inspection, as the looseness may only appear during serviceability loading. Cracking or excessive corrosion of the connector or gusset plates or the fasteners, as well as permanent deformation of the connection or members framing into it, may be indications of loose connections. Also, fasteners with missing washers or improper thread engagement are more susceptible to becoming loose over time, and should be inspected more closely. Tapping the connection with a hammer is one method of determining if the connection is loose.

The other deficiencies typically associated with connections are corroded or cracked connectors or gusset plates.

Severity

The severity of the connection deficiency shall be based on the condition of the worst component within the connection. This means that the connection will be rated based on the looseness or corrosion of the worst component. In the case of truss members, the connection shall be taken as the entire joint or node location, including both gusset plates in and out of plane, with all members that frame in. All connecting member plates shall be inspected with the overall connection rating based on the worst of these components. For Bailey Bridges, the Bailey panel connection pin shall be rated as a connection. The other connections, such as transom clamps and raker pins are too numerous to rate individually. They still should be inspected, but problems should be noted as either a maintenance need or a performance deficiency (as described in Section 5 and 6 of Part 2) for the floor beam or truss bracing elements respectively.

The location of the loose or missing fasteners, as well as areas of corrosion on gusset plates, should be described.

The severity can be determined as outlined below for the various components within the connection:

1. The severity of loose connections depends largely on the number of loose or missing fasteners relative to the total number in the connection. The severity description involves the determination of this ratio.

2. The severity of gusset plates depends on the amount of severe or very severe corrosion or cracks relative to the total plan area. The severity description involves this ratio.

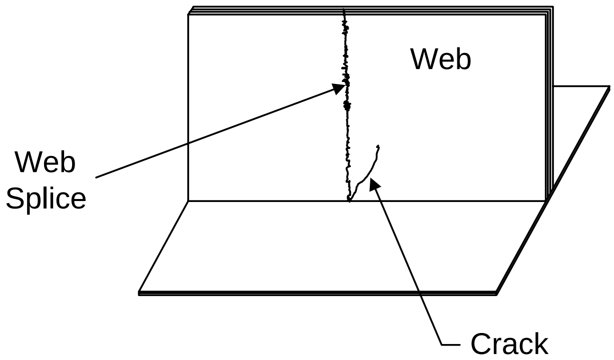
Table 2.2: Severity of Connection Deficiency for Connections in Steel

Connection Deficiency	Loose Fasteners	Gusset Plate with Severe or Very Severe Corrosion or Cracks
Light	< 5% Loose	< 5% of Plan Area
Medium	5 to 10% Loose	5 to 10% of Plan Area
Severe	> 10% Loose	> 10% of Plan Area

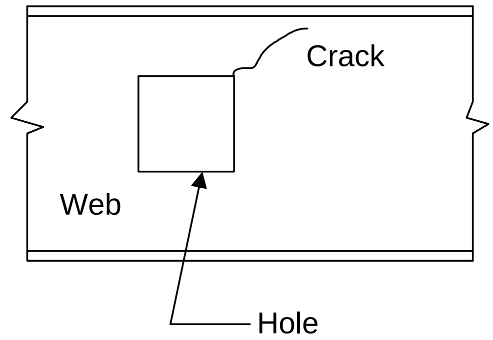
Figure 2.3.1 Medium Corrosion of Steel Beams

Figure 2.3.2 Very Severe Permanent Deformations by Impact

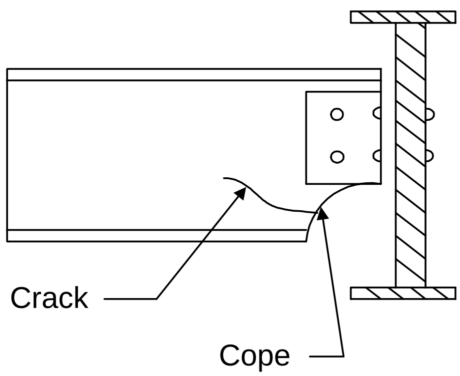
Figure 2.3.3(a) Very Wide Cracks in a Diaphragm



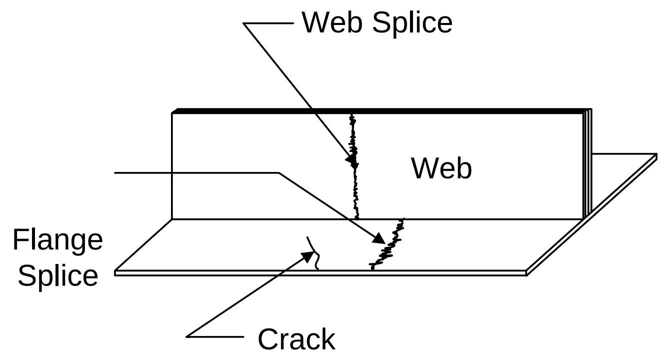
Crack in Web at Web Splice



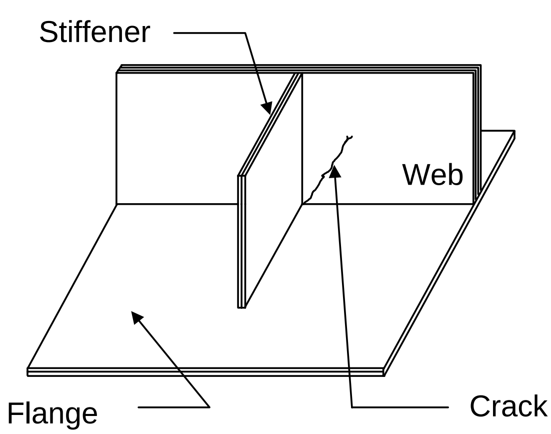
Crack at Hole in Web



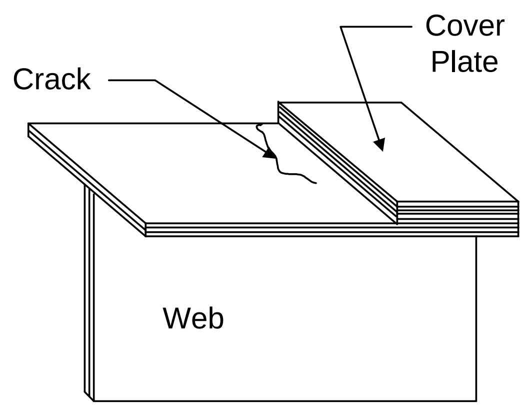
Crack in Cope of Web at a Connection



Crack in Flange at Flange Splice

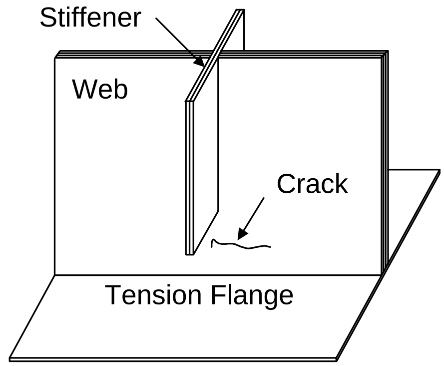


Crack in Web at Stiffener

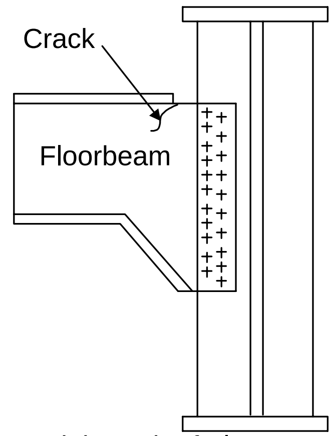


Crack at End Weld of Flange Cover Plate

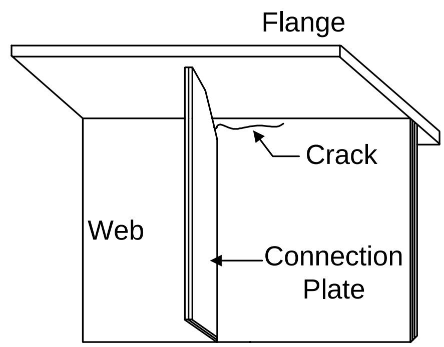
Figure 2.3.3(b) Common Crack Locations in Steel



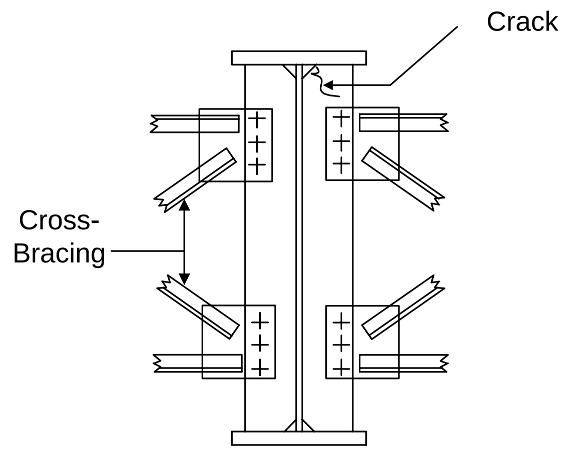
Girder Web Crack Between Cut-Short Stiffener and Tension Flange



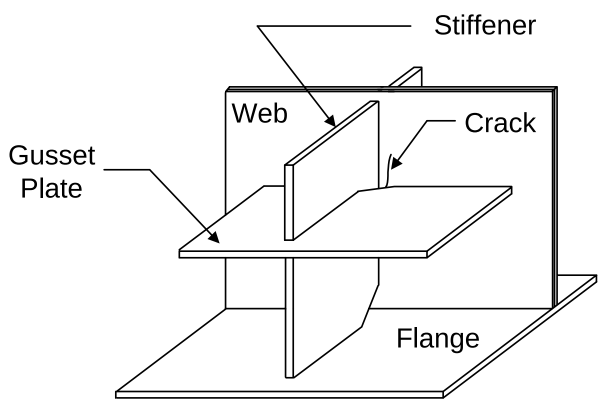
Crack in Web of Floor Beam at Cut-Short Tension Flange



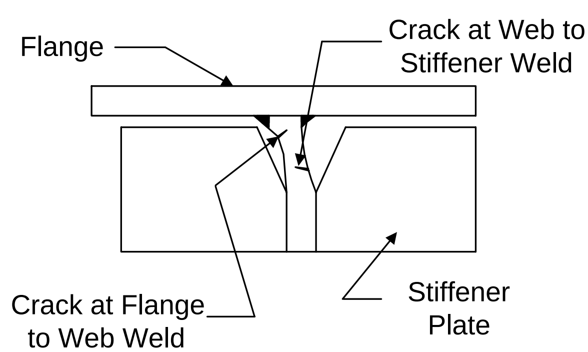
Girder Web Crack Behind Chamfer of Connection Plate



Crack in Cross-Bracing Connection Plate



Vertical Web Crack Behind Chamfer of Horizontal Gusset Plate



Cracks at Double Curvature in Web Plate From Flange Movements

Figure 2.3.3(b) Common Crack Locations in Steel (cont'd)

2.4 WOOD

Wood was one of the earliest materials used for structures, and is still in common use today. This is largely due to its availability in a variety of structural sizes and ease of handling.

The following defects commonly occurring in wood are described:

- Weathering, Checks, Splits and Shakes;
- Rot or Decay;
- Insect Damage;
- Abrasion and Wear;
- Cracking, Splintering, Crushing and Shattering;
- Fire and Chemical Damage;
- Loose Connections.

2.4.1 WEATHERING, CHECKS, SPLITS AND SHAKES

Weathering is the gradual deterioration of wood due to exposure to the actions of sun, rain, wind, frost and atmospheric pollutants. Weathering of untreated wood is accompanied by softening of the surface layer, numerous small checks, splits and shakes, a gray discoloration and "barn-board" appearance. Treated wood weathers more slowly to a gray-brown colour and may exhibit a rough "wash-board" appearance. Light weathering is shown in Figure 2.4.1(a).

Checks are longitudinal tissue separations on the side grain of wood members.

Splits are more severe tissue separations extending from the side into the end grain.

Shakes are tissue separations which follow the circular annual growth rings, and are usually visible on the end grain.

Checks, splits and shakes are illustrated in Figure 2.4.1(b).

Severity

Light - Tissue separations are short and extend for less than 5% into the member.

Medium - Tissue separations are long and extend for 5% to 10% into the member.

Severe - Tissue separations are long and extend for 10% to 20% into the member.

Very Severe - Tissue separations are long and extend for more than 20% into the member.

2.4.2 ROT OR DECAY

Rot or decay is the biological decomposition of wood caused by micro-organisms called fungi. Rot develops in progressive stages, usually through cracks, knots, holes and at the ends of members. The growth of fungi requires the presence of adequate moisture, a supply of oxygen and a favourable (warm) temperature. The absence of any of these factors will greatly inhibit or prevent fungal growth. The most common method of reducing rot or decay in wood is by pressure treatment with preservatives.

The following areas are typically prone to decay:

- Wood in contact with soil;
- Wood at the water line;
- Surfaces in contact where water can be trapped, such as, connections and bearing areas;
- At checks, splits, shakes and cracks, through which moisture can penetrate the wood.

Three types of rot may be identified in wood; namely, white rot, brown rot and soft rot.

White rotted wood has a bleached appearance, and in advanced stages the wood appears as a grey fibrous mass. It develops at or above ground contact and may attack both the surface and interior portions of wood.

Brown rotted wood has a reddish-brown appearance, and in advanced stages the wood has a checked or crumbly surface. It develops at or above ground contact and may attack both the surface and interior portions of wood.

Soft rotted wood has a soft, spongy surface, and in advanced stages the wood has a charred appearance. It usually develops below ground level or under water, and usually attacks only the surface of the wood.

The surface appearance of rotted wood is shown in Figure 2.4.2.

Severity

Light - Slight change in colour. The wood sounds solid and cannot be penetrated by a sharp object.

Medium - Surface is discoloured with black and brown streaks. The wood sounds hollow when tapped and offers limited resistance to penetration by a sharp object.

Severe - Surface is fibrous, checked or crumbly and fungal fruiting bodies are growing on it. The wood sounds hollow when tapped and offers little resistance to penetration by a sharp object.

Very Severe - The wood can be crumbled and disintegrated with ease.

2.4.3 INSECT DAMAGE

Defects in wood caused by insects are a consequence of the tunnelling and boring by larvae or mature insects through the wood resulting in loss of section. Termites, carpenter ants and wood-boring beetles are the most common insects that attack wood in Ontario. Their appearance is shown in Figure 2.4.3(a), and the resulting appearance of insect damaged wood is shown in Figure 2.4.3(b).

The severity of the insect damage can be judged by the number of holes and tunnels on the surface of the wood and by the number of insects around the area.

Severity

Light - Occasional entrance or exist holes are present. The wood is solid and cannot be easily penetrated by a sharp object.

Medium - Several entrance or exit holes are visible, and larvae or mature insects may be observed. The wood sounds hollow when tapped, and offers limited resistance to penetration by a sharp object.

Severe - Extensive tunnelling and holes are present in the wood. Larvae and insects are readily visible. The wood sounds hollow when tapped, and offers little resistance to penetration by a sharp object.

Very Severe - Extensive tunnelling, holes, larvae and insects present. Wood can be crumbled and is disintegrated with ease.

2.4.4 ABRASION AND WEAR

Abrasion is the deterioration of wood brought about by vehicles or snowplough blades scraping against wood surfaces, such as, decks, curbs, railings or piers.

Wear is usually the result of dynamic and/or frictional forces generated by vehicular traffic, coupled with the abrasive influence of sand, dirt or debris. It can also result from the friction of ice or water-borne particles against partly or completely submerged members. The surface of the wood appears worn and cracked with some loss of section. Wear of a wood deck and abrasion by ice are illustrated in Figures 2.4.4(a) and 2.4.4(b) respectively.

Severity

Light - Slight surface wear with less than 5% section loss.

Medium - Surface wear more noticeable with 5% to 10% section loss.

Severe - Loss of section between 10% to 20%.

Very Severe - Loss of section in excess of 20%.

2.4.5 CRACKING, SPLINTERING, CRUSHING AND SHATTERING

Cracking, splintering, crushing and shattering are forms of physical damage which result from vehicular collision or from overloading of a member. Particularly susceptible are members already weakened by rot or insect attack.

A crack is an incomplete separation of the wood into two or more parts with or without space in between. Cracking across the grain is caused by flexural damage through overloading. Cracking along the grain may be due to shear failure or a continuation of a split.

Splintering is a series of localized tensile failures in the wood where fragmented parts of the wood may protrude from the surface.

Crushing is a form of permanent deformation where a portion of the wood has lost its resiliency to rebound. Crushing at the bearings occurs due to excessive compression. Crushing may also occur prior to a flexural failure.

Shattering is a combined form of crushing and splintering resulting from impact.

Crushing and splintering of wood due to vehicular impact is shown in Figure 2.4.5.

Severity

Light	- Damage is mainly superficial with less than 5% section loss.
Medium	- Considerable damage with 5% to 10% section loss.
Severe	- Significant damage with 10% to 20% section loss.
Very Severe	- Extensive damage with section loss in excess of 20%.

2.4.6 FIRE AND CHEMICAL DAMAGE

Fire damage is evidenced by charring and is usually confined to the wood surface. Connectors may sustain more damage from fire than the members connected. Such damage to connections is manifested by large deformations of the connector plates and fasteners, and by loose or misaligned joints.

Chemical damage may result from the use of non-preservative chemicals on the wood surface over a long period of time, or where the wood comes in contact with corrosive chemicals resulting from accidental spills. Such damage affects the wood surface and metal connectors. The effect of chemicals on the wood is a softening of the surface accompanied by loss of strength. The effect on metal connector plates and fasteners is less critical except in certain circumstances; for example, on fasteners with low corrosion resistance.

Figures 2.4.6(a) and 2.4.6(b) shows fire and chemical damaged wood.

Severity

Light	-	Slight charring or softening of the wood surface with less than 5% section loss. Connectors unaffected.
Medium	-	Deeper charring or softening with 5% to 10% section loss. Connectors slightly loosened.
Severe	-	Section loss between 10% and 20% with several connectors loosened or deformed.
Very Severe	-	Extensive damage with section loss greater than 20% at critical locations. Many loose and severely deformed connectors.

2.4.7 CONNECTION DEFICIENCIES

Wood members are normally connected with common wire nails, spikes, bolts, shear plates, split rings, metal framing connectors or glulam rivets. Most connections are loosened due to repetitive or dynamic loads, wear or decay of members connected, and corrosion of the connectors.

Loose connections may not always be detectable by visual or hands-on inspection, as the looseness may only appear during serviceability loading. Cracking or excessive corrosion of the plates or fasteners, as well as permanent deformation of the connection or members framing into it, may be indications of loose connections.

A loose connection joining wood members is shown in Figure 2.4.7.

Severity

The severity of the connection deficiency shall be based on the condition of the worst component within the connection. This means that the connection will be rated based on the looseness, decay or corrosion of the worst component. In the case of truss members, the connection shall be taken as the entire joint or node location, including both gusset plates in and out of plane, with all members that frame in. Each connecting member and the plates shall be inspected with the overall connection rating based on the worst of these components.

The location of the loose or missing fasteners, as well as areas of corrosion any gusset plates, should be described. Any unintended gaps that are observed should be measured and recorded.

The severity can be determined as outlined below for the various components within the connection:

1. The severity of loose connections depends largely on the number of loose or missing fasteners relative to the total number in the connection. The severity description involves the determination of this ratio.

2. The severity of gusset plates depends on the amount of severe or very severe corrosion or cracks relative to the total plan area. The severity description involves this ratio.

Table 2.4: Severity of Connection Deficiency for Connections in Wood

Connection Deficiency	Loose Fasteners	Gusset Plate with Severe or Very Severe Corrosion or Cracks
Light	< 5% Loose	< 5% of Plan Area
Medium	5 to 10% Loose	5 to 10% of Plan Area
Severe	> 10% Loose	> 10% of Plan Area

Figure 2.4.1(a) Light Weathering in Wood Members

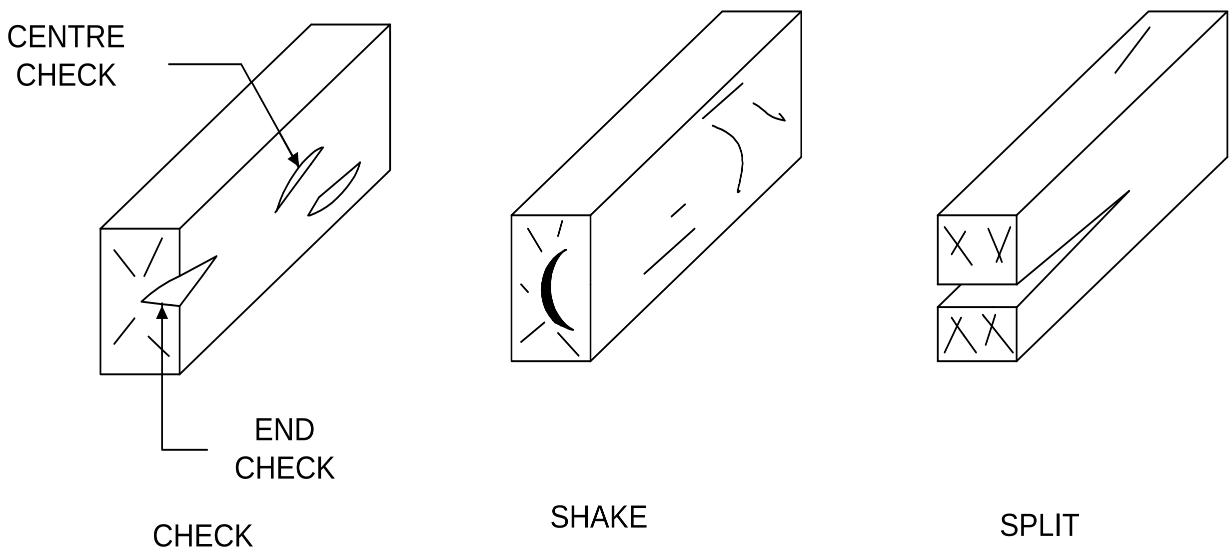
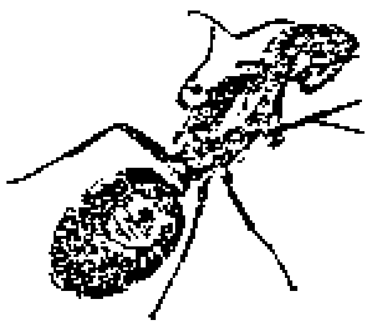


Figure 2.4.1(b) Checks, Shakes and Splits in Wood

Figure 2.4.2 Very Severe Brown Rot

Termite



Carpenter Ant

Wood Boring Beetle
(Larva and Adult)

Figure 2.4.3(a) Wood Boring Insects

Figure 2.4.3(b) Very Severe Insect Damage in Wood

Figure 2.4.4(a) Very Severe Wear in a Wood Deck

Figure 2.4.4(b) Very Severe Abrasion on a Wood Pile Due to Ice

Figure 2.4.5 Very Severe Crushing and Splintering of Wood Due to Vehicular Impact

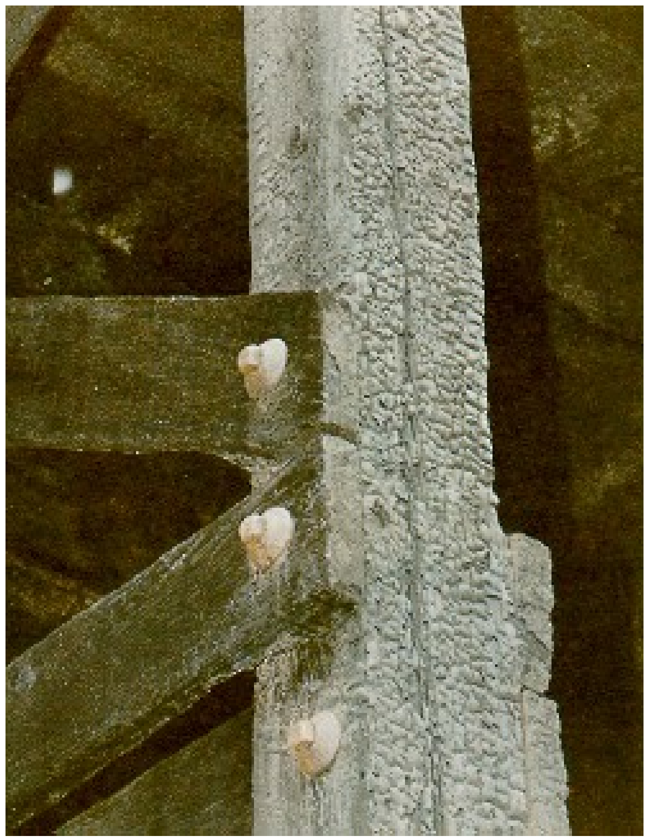


Figure 2.4.6(a) Medium Fire Damage on Wood

Figure 2.4.6(b) Light Chemical Damage on Underside of a Wood Deck

Figure 2.4.7 Loose Connection in Wood (25 mm gap measured)

2.5 MASONRY

Masonry is made of stones or bricks bonded together by mortar. Although not a common construction material today, masonry was used in Ontario, usually in retaining walls, abutments, piers or arches, primarily in the 19th century while brick masonry was only rarely used in highway structures. Types of masonry construction are ashlar masonry, squared stone masonry and rubble masonry.

The following defects commonly occurring in masonry are described:

- Cracking;
- Splitting, Spalling and Disintegration;
- Loss of Mortar and Stone.

2.5.1 CRACKING

A crack is an incomplete separation into one or more parts with or without space in between. Cracks develop in masonry as a result of non-uniform settlement of the structure, thermal restraint, frost action and overloads.

Cracks develop either at the interface between the stone and mortar, following a zig-zag pattern, when the bond between them is weak; or, go through the joint and stone, in a straight line, when the mortar is stronger than the stone, as shown in Figure 2.5.1.

Severity

Hairline cracks - less than 0.1 mm wide.

Narrow cracks - between 0.1 and 0.3 mm wide.

Medium cracks - between 0.3 and 1.0 mm wide.

Wide cracks - greater than 1.0 mm wide.

2.5.2 SPLITTING, SPALLING AND DISINTEGRATION

SPLITTING is the opening of seams or cracks in the stone leading to the breaking of the stone into large fragments.

SPALLING is the breaking or chipping away of pieces of the stone from a larger stone.

DISINTEGRATION is the gradual breakdown of the stone into small fragments, pieces or particles.

The splitting, spalling and disintegration of masonry is caused by the actions of frost, weathering and abrasion; or, by the actions of acids, sulphates or chlorides, which cause deterioration in certain types of stones, such as limestone. The splitting, spalling and disintegration of masonry are shown in Figure 2.5.2.

Severity

Light	-	Hairline cracking and minor loss of stone surface with loss of section up to 50 mm.
Medium	-	Narrow cracking or chipping away of stone with loss of section between 50 and 100 mm.
Severe	-	Spalling and disintegration of stone with loss of section between 100 and 150 mm.
Very Severe	-	Extensive spalling and disintegration of stone with loss of section in excess of 150 mm.

2.5.3 LOSS OF MORTAR AND STONES

Loss of mortar is the result of the destructive actions of frost, erosion, plant growth or softening by water containing dissolved sulphates or chlorides. Once the mortar has disintegrated it may lead to loss of stones. It should be noted that some structures have been built without the use of mortar.

Figure 2.5.3 shows evidence of loss of mortar in a masonry arch.

Severity

Light	-	Mortar lost from the joints in a few places, to a depth of 20 mm.
Medium	-	Mortar lost from the joints over an extended area, to a depth between 20 and 50 mm.
Severe	-	Extensive loss of mortar resulting in the loss of a few stones.
Very Severe	-	Extensive loss of stones endangering the stability of the structure.

Figure 2.5.1 A Wide Crack Through the Stone in a Masonry Pier

Figure 2.5.2 Very Severe Splitting, Spalling and Deterioration in Masonry.

Figure 2.5.3 Very Severe Loss of Mortar and Stone in a Masonry Arch

2.6 ALUMINUM

Aluminum is often used in railings, splash guards, drainage systems, signs and sign supports.

The following defects commonly occurring in aluminum are described:

- Corrosion;
- Cracking;
- Loose Connections.

2.6.1 CORROSION

Corrosion in aluminum is usually a uniform, gradual oxidation of the surface in the presence of air and moisture. Aluminum has a strong resistance to corrosion deterioration after the initial formation of aluminum oxide, a dense and very adherent film, which protects the underlying metal and inhibits further corrosion.

However, in less than ideal circumstances this protective layer may fail to form, or be penetrated and broken down to expose the underlying metal. The process of corrosion will then continue with progressive loss of section.

Factors which affect this are the presence or exposure of the aluminum to de-icing salts, industrial fumes, water containing dissolved chemicals, bird droppings and surface scratches. Tight corners, especially around joints and connections, which entrap moisture and debris are, particularly, susceptible to progressive corrosion. In addition, contact with other metals and concrete results in galvanic and chemical corrosions.

GALVANIC CORROSION occurs at bi-metal joints. Where aluminum comes in contact with other metals a galvanic cell is formed in the presence of an electrolyte, such as a salt solution, resulting in the localized corrosion of the aluminum. Galvanic corrosion may affect the formation of the protective aluminum oxide film or cause the film to flake off. It is, therefore, necessary that an inert spacer, either nylon or neoprene, be placed between the two metals to prevent galvanic corrosion. Galvanic corrosion does not occur when aluminum is in contact with galvanized or stainless steel.

CHEMICAL CORROSION refers to the corrosion which takes place when aluminum comes in contact with concrete. When this happens a chemical reaction takes place between the aluminum and lime in the concrete which leads to progressive corrosion of the aluminum and loss of section. An inert spacer or bitumastic coating should be used between the concrete and aluminum to prevent chemical corrosion.

Figure 2.6.1 shows typical corrosion in aluminum.

Severity

Light - Discolouration, grey to grey-black mottled appearance. Roughened surface with light blistering. No noticeable loss of section.

Medium - Definite areas of corrosion are noticeable. Moderate blistering and surface pitting. Up to 10% loss of section.

Severe - Extensive blistering and overall pitting. 10% to 20% loss of section.

Very Severe - Very extensive blistering and overall pitting. Over 20% loss of section.

2.6.2 CRACKING

A crack is a linear fracture in the aluminum which may extend partially or completely through the material. Cracks normally develop as a result of fatigue followed by brittle fracture and excessive corrosion. Cracks may also be produced by freezing of entrapped water. Cracks initiate from either the inside or the outside surface of a member and become visible as hairline cracks on the surface. As cracks may be concealed by corrosion by-products, dirt or debris, the suspect surfaces should be cleaned prior to inspection. A crack in an aluminum component is illustrated in Figure 2.6.2.

Severity

Because of the difficulty in measuring crack widths in aluminum no severity description has been established for cracks. Rather, a general report as to the occurrence and extent of cracks should be made which identifies the location, length and width of cracks wherever possible.

2.6.3 CONNECTION DEFICIENCIES

Loose connections can occur in bolted, riveted or clamped connections. The loose condition may be caused by corrosion of the gusset plates or fasteners, cracking or failure of the individual fasteners, excessive vibration, over stressing, or simply a lack of proper tightening during construction.

Loose connections may not always be detectable by visual or hands-on inspection, as the looseness may only appear during serviceability loading. Cracking or excessive corrosion of the connector, gusset plates fasteners, as well as permanent deformation of the connection or members framing into it, may be indications of loose connections. Also, fasteners with missing washers or improper thread engagement are more susceptible to becoming loose over time, and should be inspected more closely. Tapping the connection with a hammer is one method of determining if the connection is loose.

The other deficiencies typically associated with connections are corroded or cracked gusset plates.

Severity

The severity of the connection deficiency shall be based on the condition of the worst component within the connection. This means that the connection will be rated based on the looseness or corrosion of the worst component. In the case of truss members, the connection shall be taken as the entire joint or node location, including both gusset plates in and out of plane, with all members that frame in. Each connecting member and the gusset plates shall be inspected with the overall connection rating based on the worst of these components.

The location of the loose or missing fasteners, as well as areas of corrosion on gusset plates, should be described.

The severity can be determined as outlined below for the various components within the connection:

1. The severity of loose connections depends largely on the number of loose or missing fasteners relative to the total number in the connection. The severity description involves the determination of this ratio.

2. The severity of gusset plates depends on the amount of severe or very severe corrosion or cracks relative to the total plan area. The severity description involves this ratio.

Table 2.6: Severity of Connection Deficiency for Connections in Aluminum

Connection Deficiency	Loose Fasteners	Gusset Plate with Severe or Very Severe Corrosion or Cracks
Light	< 5% Loose	< 5% of Plan Area
Medium	5 to 10% Loose	5 to 10% of Plan Area
Severe	> 10% Loose	> 10% of Plan Area

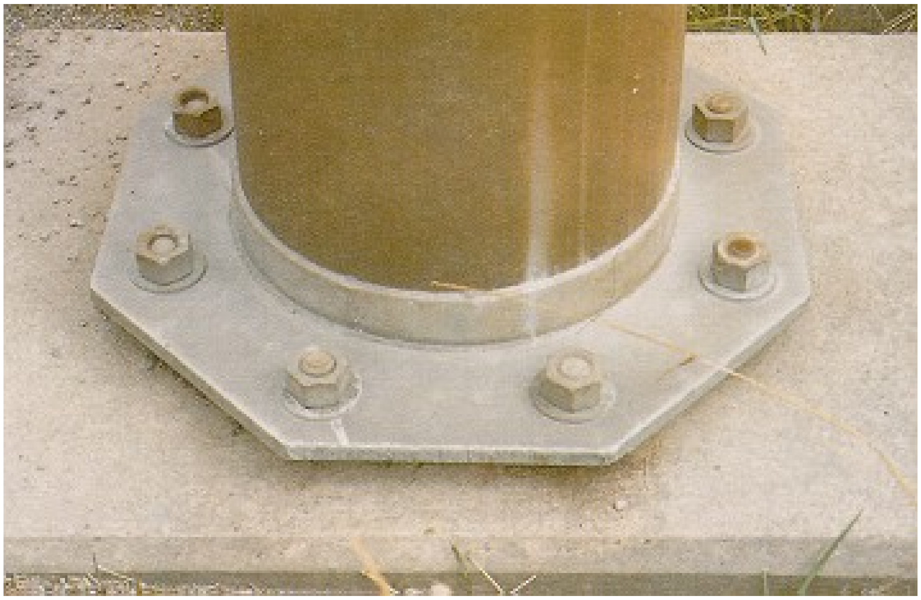


Figure 2.6.1 Light Corrosion

Figure 2.6.2 Wide Crack

2.7 ASPHALT PAVEMENT

Asphalt pavement is often used as a wearing surface on concrete, steel and wood decks. The asphalt surface provides improved safety and riding qualities when compared with a concrete surface, reduces noise, and the asphalt also offers some protection to the concrete from traffic wear, and the weather. A waterproofing membrane is also often placed on the deck surface between the deck top surface and the asphalt pavement to provide protection to the deck surface against the infiltration of moisture and de-icing chemicals, and the subsequent deterioration or decay.

Wearing Course – Is a dense, highly stable, durable, skid-resistant surface course hot mix asphalt which carries traffic. It must resist the elements and keep water out of the underlying base material.

Binder Course – The binder course is the lower layer(s) of an asphalt pavement. It is normally distinguished from the surface course when there is a distinct difference in the quality of the mixtures used. It adds much to the overall strength of the pavement structure. It supports the surface course and distributes load to the base.

Flexible Pavement – A bituminous surface on a granular base (such as on the approaches of bridges without approach slabs).

Rigid Pavement – Including composite pavements consist of a concrete slab with bituminous overlays (such as on a bridge deck or approach slab).
Defects in asphalt pavements can be related to the lack of durability of the asphalt resulting from the composition of the asphalt, poor placement practices, lack of sub-grade support, reflection cracking, or the aggressive environment in which it is placed (Reference 4).

Asphalt Defects

Asphalt defects on concrete decks or slabs are sometimes an indication of deterioration of the concrete surface. For the purposes of bridge inspection, asphalt defects can be grouped into the following two general categories:

(1) **Top-Down Defects**

- Defects that originate in the asphalt itself, which do not have an appreciable effect on the concrete deck surface below. These include:
    - i. Bond Defects (loss of bond and rippling)
    - ii. Surface Defects (ravelling, slippery surface and flushing)
    - iii. Surface Distortions (wheel track rutting)
    - iv. Isolated cracks (Light and medium isolated cracks)

(2) **Bottom-up Defects**

- Defects that probably originate in the concrete deck and are reflected in the asphalt surface. These include:
    - i. Pattern cracking (map, alligator, radial, edge cracking)
    - ii. Wide isolated cracks (transverse, longitudinal)
    - iii. Local Underlying Defects (local potholes and protrusions)

2.7.1 CRACKING

A crack is a linear fracture extending partially or completely through the pavement. Cracking in pavements may be caused by any one or a combination of the following factors; the action of vehicular wheel loading; poor quality material; poor compaction; placement or quality control; frost action; poor drainage; shrinkage due to low temperatures; temperature susceptibility of the asphalt cement binder; and as reflection cracks, which are the extension of cracks in the surface below the pavement.

Cracks are distinguished by their appearance and direction. The following types of cracks are commonly observed in pavements; longitudinal, transverse, alligator, map, and progressive edge cracking.

LONGITUDINAL cracks are roughly parallel to the direction of travel and may be situated at or near the centre of the wheel tracks, centreline of the roadway, middle of the lane, or along the pavement edges.

TRANSVERSE cracks are approximately at right angles to the pavement centreline and may extend partially or completely across the pavement.

ALLIGATOR cracks form a network of multi-sided polygons or blocks resembling the skin of an alligator. The block sizes typically range from 50 mm to 500 mm. They may occur anywhere in the pavement surface, and may be accompanied by depressions in the surface.

MAP cracks run randomly along the pavement, sometimes in a serpentine manner. They appear to consist of longitudinal and transverse cracks combined to form a 'map' pattern.

PROGRESSIVE EDGE cracks begin parallel to and usually within 300 mm of the edges of the pavement; such as, along curb edges and expansion joint dams. The cracks are either fairly straight and continuous or consist of crescent-shaped cracks in a wave formation. These cracks may progress significantly into the travelled portion of the pavement. Edge breaking of the pavement often results from these.

The various types of pavement cracks are illustrated in Figures 2.7.1(a) to 2.7.1(e).

Severity

Light
- 1 mm to 5 mm wide single or multiple cracks;
- alligator pattern established with corners of polygon blocks fracturing;
- progressive edge cracking less than 600 mm from pavement edge, either single or two parallel cracks.

Medium
- 6 mm to 10 mm wide single or multiple cracks;
- alligator pattern established with spalling of polygon blocks;
- progressive edge cracking extending between 600 mm to 900 mm from pavement edges, multiple cracks with connecting cracks.

Severe
- 10 mm to 20 mm wide single or multiple cracks;
- polygon blocks in alligator cracking are beginning to lift leaving potholes;
- progressive edge cracking extending over 900 mm from pavement edge with alligatoring of pavement along edges.

Very Severe
- Greater than 20 mm wide single or multiple cracks;
- a number of polygon blocks lifted off in alligator cracking;
- progressive edge cracking extending over 1200 mm from pavement edge with alligatoring of pavement along edges.

2.7.2 BOND DEFECTS

2.7.2.1 LOSS OF BOND

Widespread loss of bond and delamination may occur between the asphalt pavement and deck surface, between the waterproofing and the deck surface, between the waterproofing and asphalt pavement or between individual lifts of pavement.

Loss of bond and delamination is not directly visible on the pavement surface; however, they may often be detected by hammer sounding or chain drag. The accurate assessment of the extent or severity of these defects can usually only be determined by detailed deck survey methods; such as, thermography, radar and removal of the pavement.

Severity

Light	-	Loss of bond over area measuring less than 150 mm, in any direction.
Medium	-	Loss of bond over area measuring between 150 mm and 300 mm, in any direction.
Severe	-	Loss of bond over area measuring between 300 mm and 600 mm, in any direction.
Very Severe	-	Loss of bond over area measuring more than 600 mm, in any direction.

2.7.2.2 RIPPLING

Rippling is the formation of transverse undulations in the pavement surface consisting of closely spaced valleys and crests. Rippling is the result of poor bond of the pavement to the surface below with the subsequent action of wheel friction and braking forces moving the pavement 'mat' forwards, backwards and sideways.
Rippling of an asphalt pavement is illustrated in Figure 2.7.6.

Severity

Light	-	A few noticeable bumps.
Medium	-	Several bumps producing a rough ride.
Severe	-	Numerous bumps producing a very rough ride with possible loss of vehicle control.
Very Severe	-	Numerous bumps producing a very rough ride with difficulty in maintaining vehicle control and imminent danger of loss of vehicle control.

2.7.3 LOCAL UNDERLYING DEFECTS

2.7.3.1 POTHOLES

Potholes are bowl-shaped holes in the pavement caused by the penetration of water through the pavement and the subsequent heaving of the pavement due to freezing of the entrapped water and breaking up of the pavement due to traffic action. They may result from delaminations or other defects in the underlying concrete surface. Pavements already deteriorated with such defects as alligator cracking and ravelling are prone to the occurrence of potholes.

A typical example of a pothole is illustrated in Figure 2.7.4.

Severity

Light	-	Holes measuring less than 10 mm in depth.
Medium	-	Holes measuring between 10 mm to 20 mm in depth.
Severe	-	Holes measuring between 20 mm to 40mm in depth.
Very Severe	-	Holes measuring over 40 mm in depth.

2.7.3.2 LOCAL PROTRUSIONS (DELAMINATIONS)

Local delaminations become visible as protrusions or bumps. These are localized upward displacements of the pavement surface (often circular in shape) typically caused by frost action either between or under the layers of asphalt. They are generally the initial indications of the formation of potholes.

Severity

Light	-	Protrusions measuring less than 10 mm in height.
Medium	-	Protrusions measuring between 10 mm to 20 mm in height.
Severe	-	Protrusions measuring between 20 mm to 40mm in height.
Very Severe	-	Protrusions measuring over 40 mm in height.

2.7.4 SURFACE DEFECTS

2.7.4.1 RAVELLING/SEGREGATION

Ravelling is the progressive deterioration and loss of the pavement material from the surface downward. Ravelling begins on the surface but progresses down into the asphalt. The surface appears to be breaking up into small pieces and exposing and eventually loosening the aggregates. Ravelling can occur anywhere over the surface, but is most common along curb or sidewalk faces where salt-laden roadway drainage collects, and along wheel tracks due to traffic action on pavements embrittled and weakened through aging. Severe ravelling may occur together with signs of cracking or potholes.

Ravelling of an asphalt pavement is illustrated in Figure 2.7.2.

Severity

Light	-	Noticeable loss of pavement material.
Medium	-	Shallow disintegration of the pavement surface with an open textured appearance.
Severe	-	Shallow disintegration of the pavement surface with small potholes. Very open textured appearance with loose material over the surface.
Very Severe	-	Deep disintegration of the pavement surface with numerous potholes. Very open textured appearance with loose material over the surface.

2.7.4.2 FLUSHING

Flushing is the migration of asphalt upwards to the pavement surface in pavements with too much asphalt in the mix. It commonly occurs in the wheel tracks, especially during hot weather, by the action of vehicle traffic pressing and squeezing the excess asphalt to the surface. Flushing of the surface of an asphalt pavement is illustrated in Figure 2.7.7.

Severity

Light - Visible colouring of the pavement surface occurring in localized areas.

Medium - Distinctive colouring of the pavement surface with excess asphalt free on the pavement surface.

Severe - Free asphalt gives the pavement surface a 'wet' look; vehicle traffic leaves visible tire marks and impressions on the pavement surface.

Very Severe - Excessive free asphalt on the pavement surface with a 'wet' look. Footprints leave visible impressions in the pavement surface.

2.7.4.3 SLIPPERY ASPHALT SURFACE

Slippery asphalt surfaces may result from flushing or from the polishing of the coarse surface aggregates by the action of repetitive vehicular traffic.

Severity

There are no severity descriptions given for slippery surfaces as this is a serious and potentially hazardous situation. Where evidence of slippery surfaces is noted, a suspected performance deficiency should be recorded and the District and Regional Traffic Office shall be notified.

2.7.5 SURFACE DISTORTIONS

2.7.5.1 WHEEL TRACK RUTTING

Wheel track rutting is the formation of longitudinal depressions in the pavement at the locations of the wheel tracks of vehicles resulting from the compaction and shoving of the pavement laterally under repeated vehicle traffic.

Wheel track rutting and its measurement is illustrated in Figure 2.7.5.

Severity

Light - Rutting less than 10 mm deep.

Medium - Rutting from 10 mm to 20 mm deep.

Severe - Rutting from 20 mm to 40 mm deep.

Very Severe - Rutting greater than 40 mm deep.

Figure 2.7.1(a)   Medium Longitudinal Crack

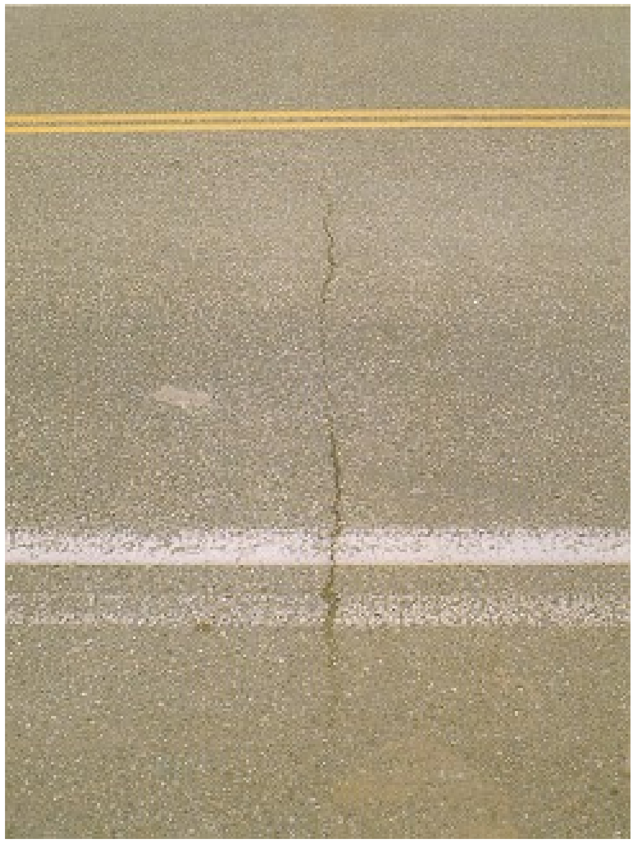


Figure 2.7.1(b) Medium Transverse Crack

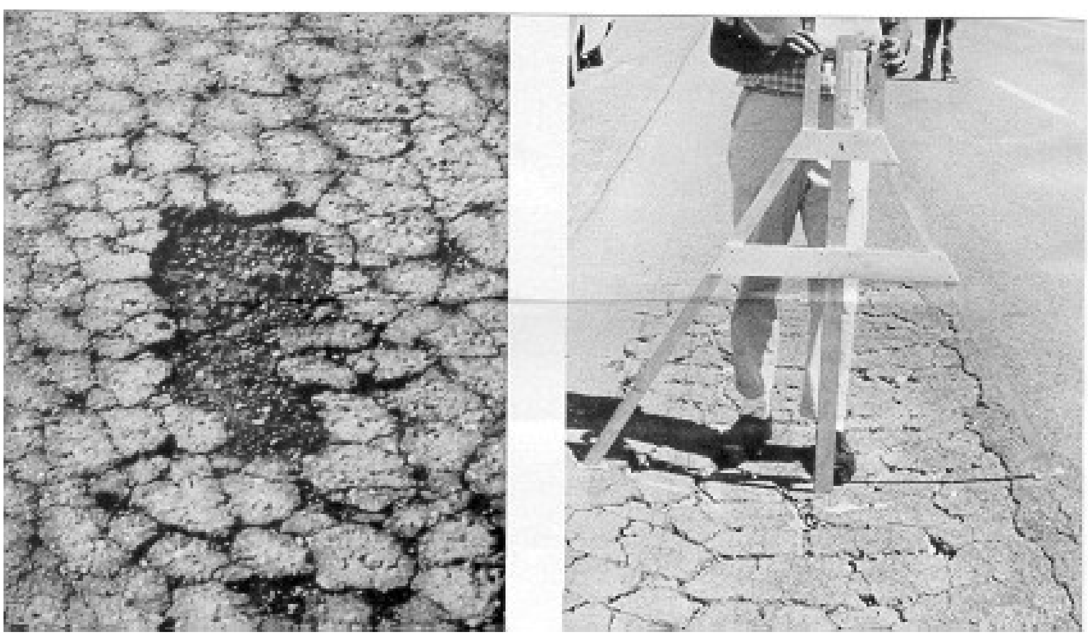


Figure 2.7.1(c) Severe Alligator Cracks

Figure 2.7.1(d) Light Map Cracks

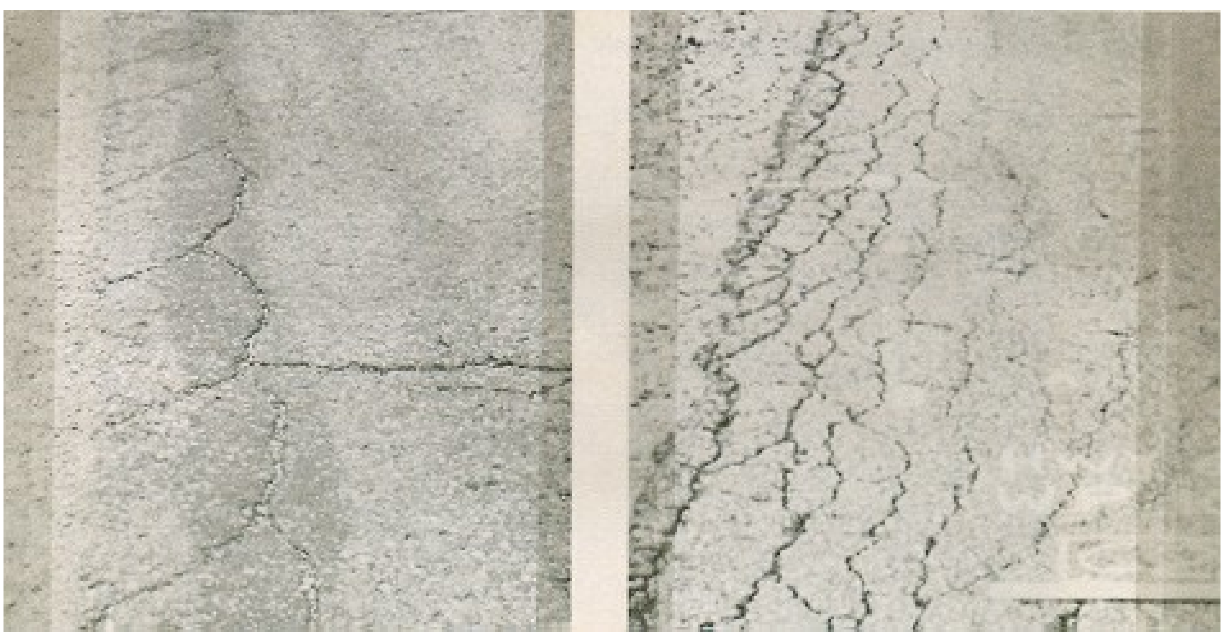


Figure 2.7.1(e) Medium Progressive Edge Cracks

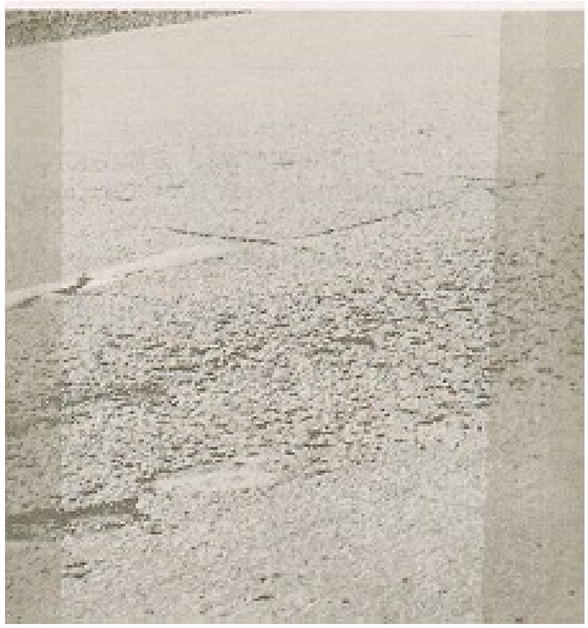


Figure 2.7.2 Severe Ravelling

Figure 2.7.4 Severe Pothole

Figure 2.7.5 Medium Wheel Track Rutting

Figure 2.7.6 Severe Rippling

Figure 2.7.7 Severe Flushing

Figure 2.7.8 Slippery Surface

2.8 COATINGS

Coating defects are not necessarily serious in themselves; however, they are indicative of a potential weakness in the coating and eventual loss of protection for the surface coated. No criteria are given for the severity of material defects in coatings, therefore, they do not need to be classified as to severity. However, their presence and the area affected should be noted and recorded.

There are several types of material defects that commonly occur in coatings (References 5 to 8), which can be grouped into the following three categories:

(a) Coating Related Defects

These are defects which are related to the basic chemistry or composition of the coating and reaction of the coating materials with each other and the environment. Common defects of this type are:

- Checking or Crazing
- Cracking
- Alligatoring
- Chemical Attack
- Chalking

(b) Adhesion Related Defects

These are defects which are usually a result of incorrect coating selection, contaminated substrate or improper surface preparation. Common defects of this type are:

- Undercutting
- Blisters
- Intercoat Delamination
- Peeling
- Underfilm Corrosion

(c) Application Related Defects

These are defects which are usually a result of the improper application of the coating. Common defects of this type are:

- Bridging
- Edge Defects
- Shadows
- Overspray
- Pinholing
- Runs
- Sags
- Pinpoint Rusting

2.8.1 COATING RELATED DEFECTS

CHECKING or CRAZING usually appears as a fine system of minute cracks in a checkerboard pattern. This is a surface defect and does not necessarily penetrate the full depth of the coating. They are usually inherent in the coating as some pigments combined with some vehicles will tend to cause checking or crazing to occur. They may also be caused by the weathering process, including wetting and drying, heating and cooling, exposure to sunlight and contraction of the coating as it dries or cures, Figure 2.8.1(a).

CRACKING may result from the effects of weathering or continued polymerisation of the coating materials over time. An oxidizing or catalyzed coating applied over a very smooth surface may crack due to shrinkage and poor adhesion to the substrate. Cracking is an extension of the checking process and usually occurs in a linear pattern and penetrates completely through the coating. The cracked coating tends to spall off exposing bare substrate, Figure 2.8.1(b).

ALLIGATORING occurs if a hard, brittle or oxidizing top coat is applied over an extensible base coat, such as an alkyd over an asphalt base. As the surface hardens and shrinks, very large irregular checks, usually several centimetres across, are formed on the surface in a characteristic alligator pattern but do not go all the way through the coating. If not over-coated with compatible material; then, the mechanism will continue until it completely penetrates to the substrate, Figure 2.8.1(c).

CHEMICAL ATTACK results as some coating materials may react adversely with some air-borne chemicals and pollutants, or as a result of accidental spillage. Oil base coatings such as alkyds are subject to damage by alkaline chemicals, Figure 2.8.1(d).

CHALKING is a surface phenomenon of some coatings that results from exposure to the action of solar radiation and the processes of weathering over a period of time. This results in a chalky or powdery appearance of the coating. It occurs because many basic resins will react with sunlight and many pigments will accelerate the process of weathering away of the resin binder between the pigment particles leaving the pigment particles free on the surface. Chalking is usually a surface defect and the coating is intact below the chalky surface; however, chalking can progress and the thickness of sound coating reduced to the point where the substrate is exposed.

2.8.2 ADHESION RELATED DEFECTS

UNDERCUTTING is the spreading of corrosion underneath the coating from a break in the coating. It is usually caused by poor surface preparation and the application of the coating over surfaces which contain mill scale or rust; or which have oil, grease or dirt, and otherwise improperly cleaned surfaces. Undercutting can also be caused by application of the coating to surfaces that are very smooth or non-porous resulting in poor adhesion of the coating. Undercutting is also promoted by high moisture vapour permeability of the coating and penetration by oxygen and salts, Figure 2.8.2.(a).

BLISTERS are dome shaped projections in paints arising from the detachment of one coat from another or from the substrate. It is generally caused either by solvents which are trapped within or under the paint film, or by water which is drawn through the paint film by the osmotic forces exerted by hygroscopic salts at the paint/substrate interface, Figure 2.8.2(b).

INTERCOAT DELAMINATION is where one coat separates from another and is usually related to poor coating application over contaminated surfaces or to too long a drying or curing period between coats, Figure 2.8.2(c).

PEELING is also a result of poor adhesion of the coating either from the substrate or from a previously applied coating. It is related to the tensile strength of the coating film itself where, if the tensile strength of the film is greater than the adherence to the surface; then, the coating will tend to peel. Peeling between coats is usually caused by contamination of the surface of the previous coat, Figure 2.8.2(d).

UNDERFILM CORROSION is the building up of corrosion under the coating without the help of a break in the coating. It is prevalent in coatings which oxidize on the surface, such as oil base and alkyd coatings. These oxidize over time to a point where they become porous to moisture, oxygen and chloride ions. This coating failure is promoted by poor surface preparation, substrate profile and surface contamination.

2.8.3 APPLICATION RELATED DEFECTS

BRIDGING across inside corners where debris has accumulated occurs if the debris is not properly cleaned off before the coating is applied. The coating, upon curing, may shrink sufficiently to bridge over the area resulting in voids under the coating. Subsequent penetration by moisture and oxygen will result in coating failure.

EDGE DEFECTS are a result of the improper or insufficient application of coatings to sharp edges and corners. The coating will tend to pull away from sharp edges and corners due to surface tension of the coating. This results in a thinner coating in these areas and, consequently, loss of film thickness and protection, Figure 2.8.3.(a).

SHADOWS often result around rivets, bolts, welds, and at other areas where there are abrupt changes in an otherwise smooth surface, and where the coating is not applied in a sufficient number of different directions resulting in incomplete coverage, Figure 2.8.3(b).

OVERSPRAY occurs when paint particles fall on the surface outside the normal spray pattern. The result is a dry spray as these particles are usually dry by the time they reach the surface. The resulting appearance is an area which is rough and dull and does not have the same sheen as other areas where the coating is properly applied. The dry spray will absorb solvent from the subsequent coats resulting in poor adhesion. Overspray areas are also typically more porous and, consequently, early coating failure can result, Figure 2.8.3(c).

PINHOLING can be caused by holding the spray gun too close to the surface so that air bubbles are entrained into the coating creating voids throughout the depth of the coating. If pinholing occurs in one coat; then, it will also tend to occur in subsequent coats, thus providing a passage through the voids to the substrate. Pinholing usually occurs in fast drying coatings, Figure 2.8.3.(d).

RUNS are a downward movement of a paint film in rivulets caused usually by overthinning, slow thinners, and/or holding the spray gun too close to the surface and depositing too much paint at one time. The perimeter of the run is often accompanied by pinholes, Figure, 2.8.3.(e).

SAGS are heavy thicknesses of paint which have slipped and formed curtains on the surface. They are caused by the same things that lead to runs, Figure 2.8.3.(e).

PINPOINT RUSTING usually occurs when insufficient thickness of coating is applied over a blast cleaned substrate. The profile peaks lack proper protection and continue to rust, Figure 2.8.3.(f).

Figure 2.8.1(a) Checking

Figure 2.8.1(b) Cracking

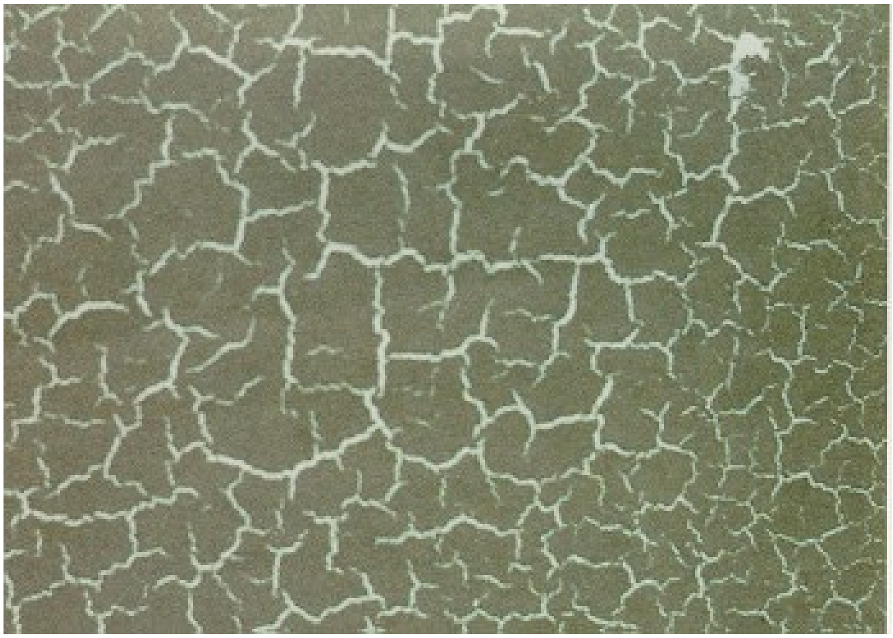


Figure 2.8.1(c) Alligatoring
(typical mud crack pattern)

Figure 2.8.1(d) Chemical Attack

Figure 2.8.2(a) Undercutting

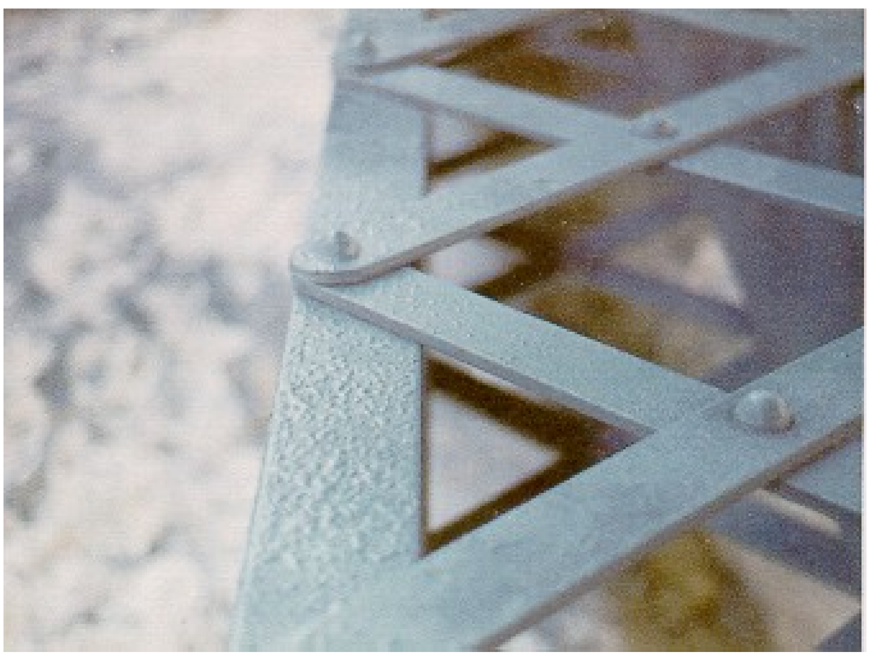


Figure 2.8.2(b) Blisters

Figure 2.8.2(c)   Intercoat Delaminations

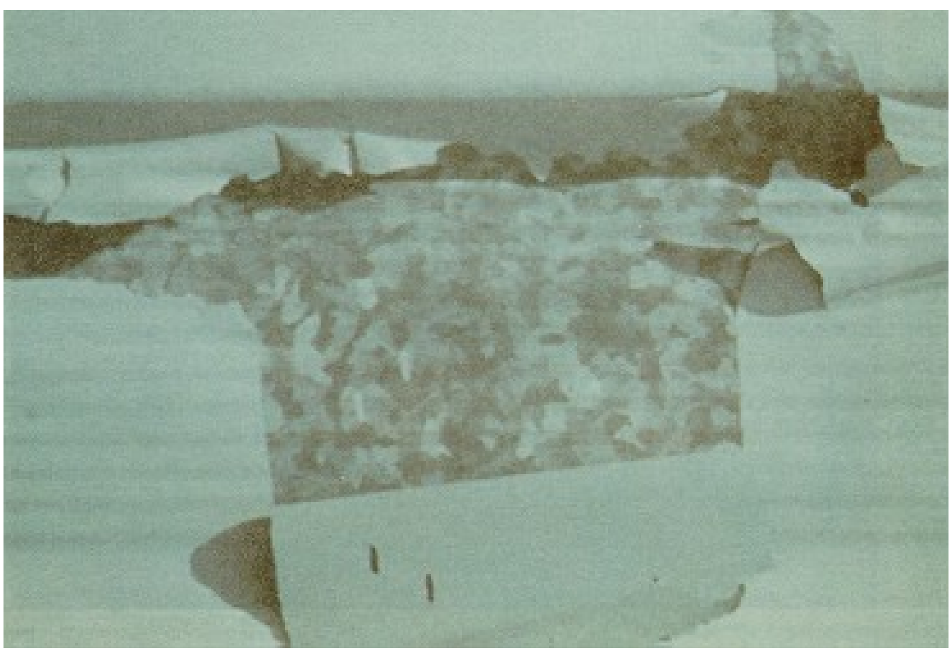


Figure 2.8.2(d)   Peeling

Figure 2.8.3(a)   Edge Defects

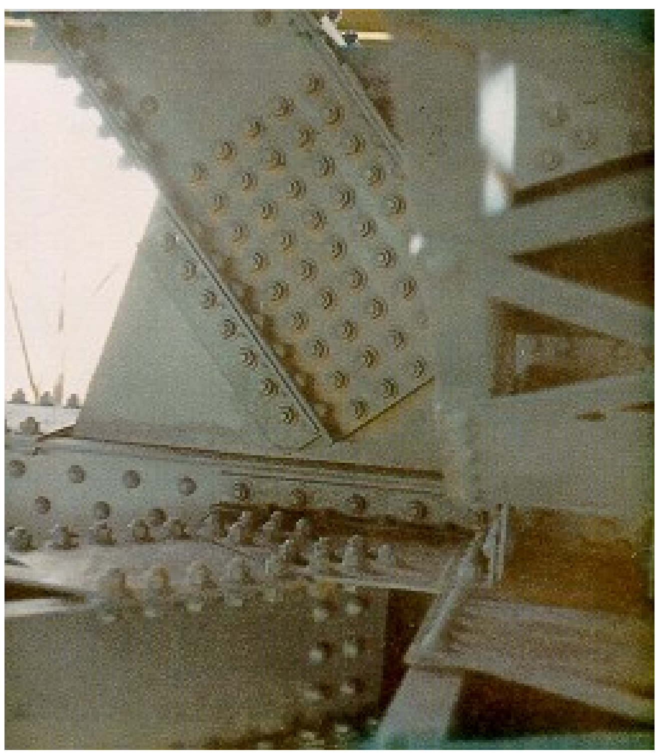


Figure 2.8.3(b)   Shadows

Figure 2.8.3(c)   Overspraying

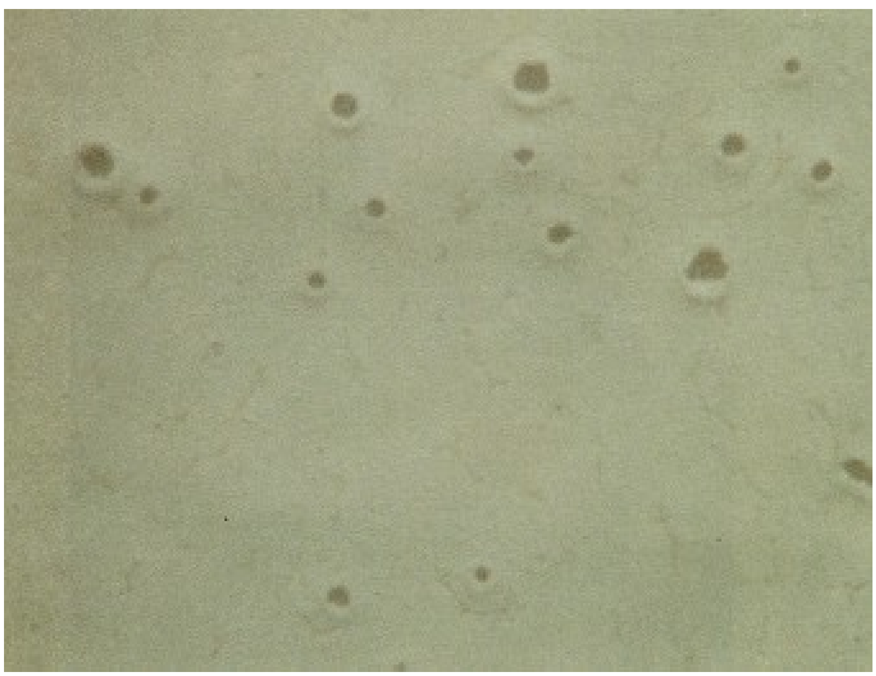


Figure 2.8.3(d)   Pinholing

Figure 2.8.3(e) Runs and Sags

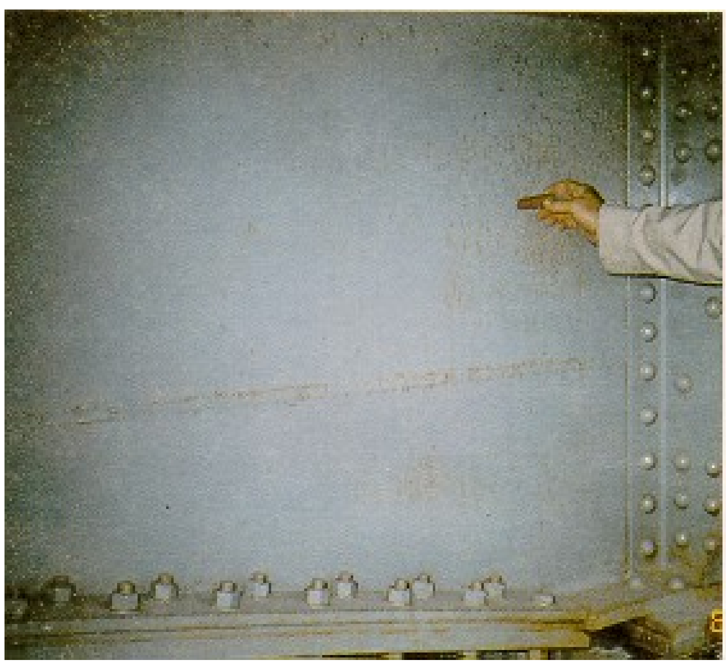


Figure 2.8.3(f) Pinpoint Rusting

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SECTION 3 - STREAMS AND WATERWAYS

Contents

3.1 STREAMS AND WATERWAYS

For the purpose of this section, a stream is defined as a body of water over or under which a structure is built. The defects produced in the stream by the presence of structure components in or near the stream are detailed in this section. Streams are to be considered as auxiliary components.

An assessment of the stream and channel stability is important for determining the need for protective measures. A stable stream and channel is one that does not change in size, form or location over time. They have fairly constant widths, well protected banks and narrow sand bars.

An unstable stream and channel is one in which changes occur over time which are large enough to become a significant factor in the maintenance of structure components in and around the stream and channel. All alluvial channels change to some extent over time and, therefore, have some degree of instability.

There are three principal types of streams; namely, meandering, straight and braided.

A meandering stream is characterized by alternative S-bends which migrate laterally downstream. Bank erosion occurs on the outside radius while deposition occurs on the inside radius at each bend in the stream. Meandering streams may be unstable.

A straight stream is one where the length of the stream, measured down the centreline of stream, divided by the length of the valley proper is less than 1.5. A straight stream is usually not entirely free of meandering since the main current often alternates from side to side. Straight streams are usually relatively stable.

A braided stream is identified by numerous unstable interlacing channels separated by gravel or sand bars and small islands. Braided streams are usually highly unstable.

The above three types of streams are illustrated in figure 3.1.

3.1.1 MATERIAL DEFECTS OF STREAMS AND WATERWAYS

SCOUR is the removal of material from the stream bed or bank due to the erosive action of moving water in the stream. Scour may be general or local. General scour is caused by the constriction to the natural flow created by the structure, and is measured as the average depth below the original stream bed. Local scour occurs as a result of an obstruction to the flow, such as, a pier, an abutment, the toe of the embankment or accumulation of debris in the stream. Local scour is measured below the level of general scour.

DEGRADATION is the lowering of the stream bed or the widening of the stream channel due to continuous scour by the stream and usually occurring when the sediment transport capacity of the stream is enhanced by increased flow. This often results from a natural increase in the slope of the stream bed or as a result of artificial alterations. Lowering of the stream bed may also result in slumping and erosion of the stream banks, structure embankments and slope protection.

AGGRADATION is the raising of the stream bed or the narrowing of the stream channel due to deposition of material by the stream and usually results where the sediment transport capacity of the stream is decreased. This often results from a natural flattening of the stream bed gradient or as a result of artificial alterations.

ICE can cause several problems, the most common of which is ice jamming at the time of spring break-up. Ice piling against a structure may cause serious damage to the structure and ice jams may cause severe local scour by constricting the opening at the structure. Jams are frequently a result of ice flows piling up against unbroken ice at a flattening of the stream gradient. The impact of ice flows can cause bending of exposed steel piles and the breaking of timber piles.

PIPING is the subsurface removal of fines by the movement of water through the ground or embankments.

CHANGES IN ALIGNMENT may occur as the result of fluctuating water levels and changes in stream velocity.

Figure 3.1.1 illustrates material defects commonly occurring in streams.

3.1.2 PERFORMANCE DEFECTS IN STREAMS AND WATERWAYS

Performance defects in streams and waterways are based upon the ability of the structure opening to accommodate the stream flow; the frequency of flooding at the structure; and material defects of streams that adversely affect other components of the structure.

BLOCKAGE of the stream channel may occur as a result of accumulations of debris due to natural causes, beavers dams, or due to aggradation of the stream bed or banks. Large quantities of debris are carried down by relatively fast-flowing streams having erodible banks.

FLOODING over the structure and adjacent roadways occurs if the opening under the structure was not designed to accommodate the volume of water passing through it. Flooding may also occur as a result of channel blockage.

UNDERMINING is the progression of the scour under the structure foundations.

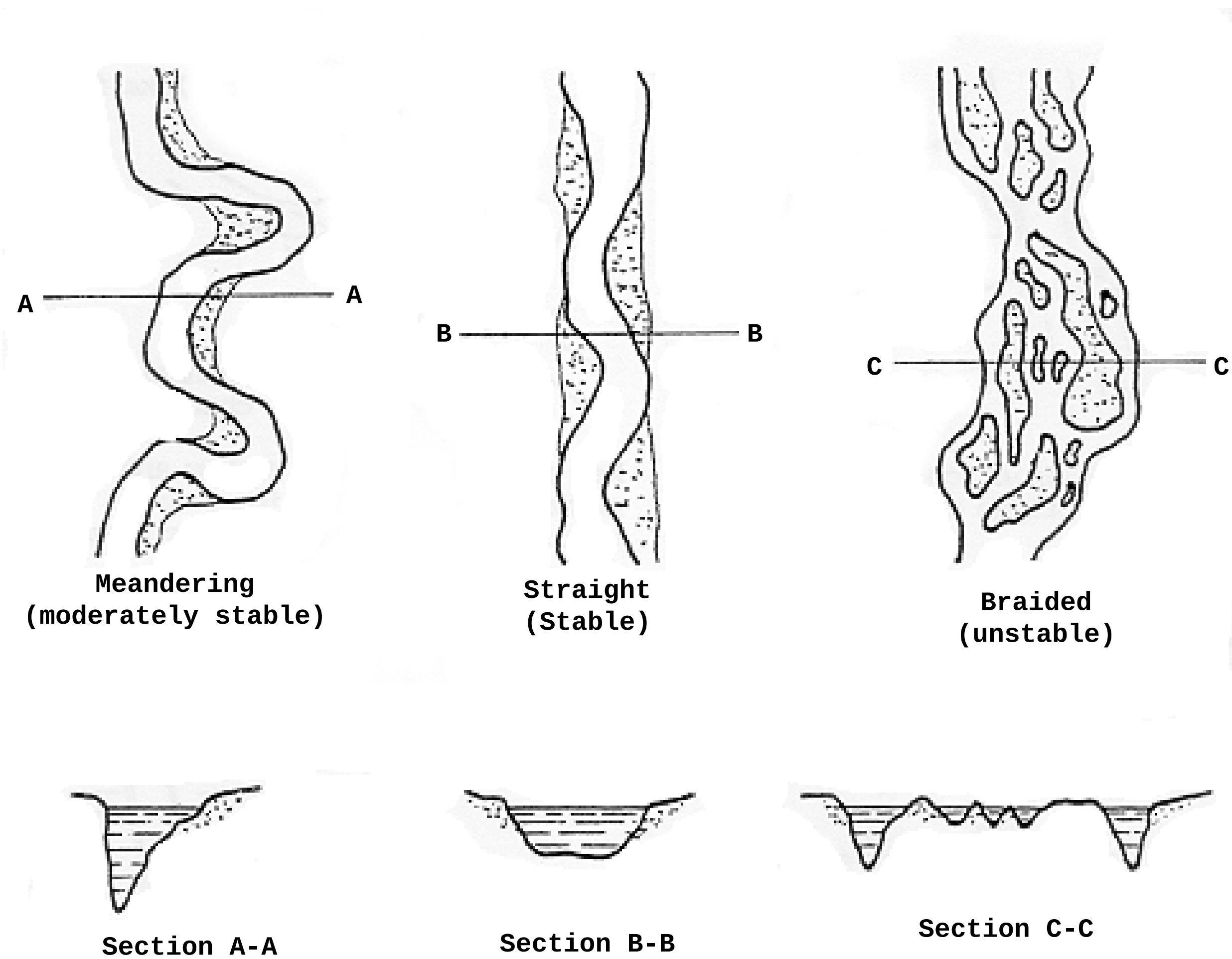
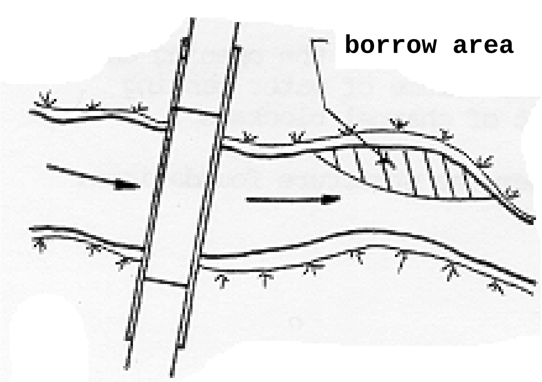
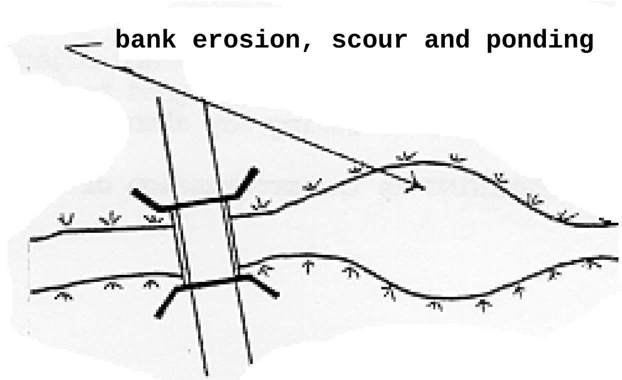


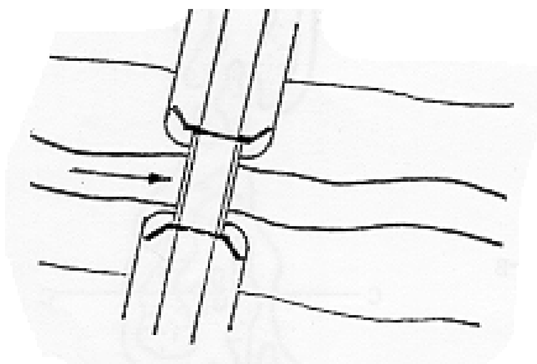
FIGURE 3.1 Principle Types of Streams



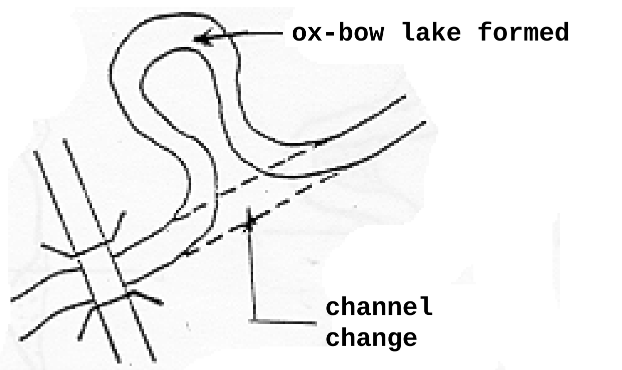
Removing large quantities of gravel gravel from channel bottom causes degradation upstream



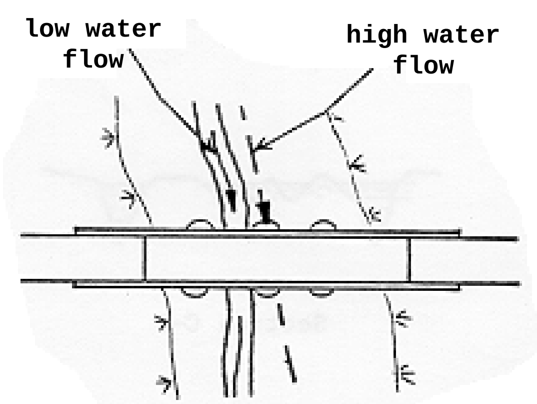
A firm channel bottom or constriction causes scour, bank ersion and ponding downstream



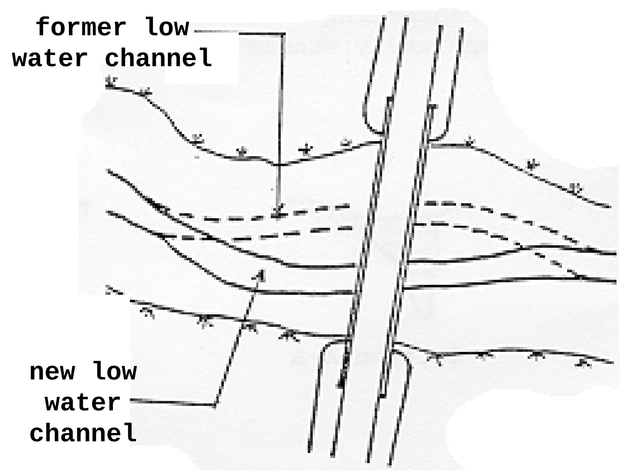
Channel constriction produces scour around the bridge during flood



New channel cuts off ox-bow and steepens channel profile with increase in flow velocity and degradation upstream



Scour around piers is influenced by location of pier to flow. Note change of flow at high water



New water channel may be fored after a flood

Figure 3.1.1 Typical Material Defects in Streams (cont)

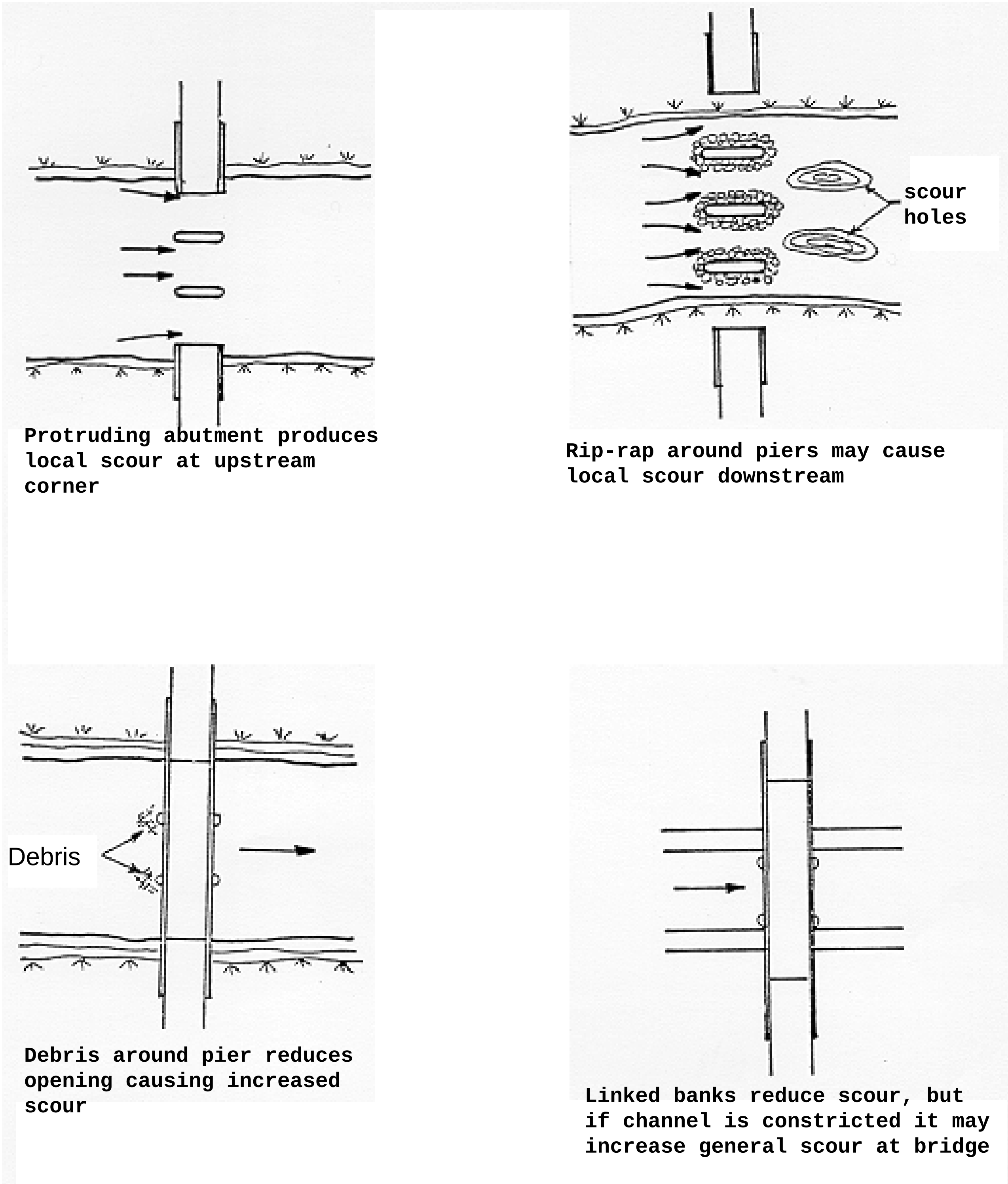


Figure 3.1.1 Typical Material Defects in Streams

SECTION 4 - EMBANKMENTS AND SLOPE PROTECTIONS

Contents

4.1 EMBANKMENTS

Embankments are sloped fills or cuts in the vicinity of the structure. The purpose of the embankments is to provide for a stable change of grade between the roadway and the surrounding ground surface, streams or other roadways under the structure. Another purpose of the embankments is to provide support for the foundations where they are situated within the embankments.

Embankments are normally constructed from earth, rock or a combination of these materials. The sloping faces of embankments may be protected from the effects of erosion or scour by slope protection systems.

Embankments are to be considered as primary components if they support the foundation, otherwise, they are to be considered as secondary components.

4.1.1 MATERIAL DEFECTS OF EMBANKMENTS

EROSION is the gradual wearing away or removal of material by surface drainage or wind. Sources of surface drainage potentially leading to erosion are leakage through expansion joints onto the embankment, runoff around the ends of wingwalls, discharge from deck drains directly above the embankment and abutment and wingwall subdrains discharging onto the embankment.

PIPING is the subsurface removal of fines by movement of water through the ground or embankment.

WASHOUT is the removal of material from the ground or embankment by subsurface or surface erosion.

SCOUR is the removal of embankment material by the action of stream flow.

4.1.2 PERFORMANCE DEFECTS OF EMBANKMENTS

Performance defects in embankments are related to their ability to maintain a stable grade separation between the roadway and the surrounding terrain without appreciable movement. Performance defects are also related to the ability of the embankments to provide support to the foundations without appreciable movements where the foundations are supported by the embankments.

MOVEMENT of embankments may consist of:
- settlement of embankment or roadway approaches;
- sliding of the slopes or toes of embankments;
- surface or deep seated slips.

Movement of embankments may result from:
- improper or inadequate compaction of fill;
- instability of the underlying soils;
- instability of the embankment material;
- loss of embankment material due to erosion, scour; piping, undermining, disintegration or other causes (e.g. burrows).

UNDERMINING is the progression of scour of the embankment or the stream bed under the embankment.

4.2 SLOPE PROTECTIONS

The purpose of the slope protections is to prevent the erosion or scour of embankments and stream banks in the vicinity of structures. A secondary purpose is to control the growth of grass and vegetation on steep slopes where mechanical equipment cannot be used safely.

The types of slope protections used most commonly are summarized in Table 4.2.

4.2.1 MATERIAL DEFECTS OF SLOPE PROTECTIONS

- Loss of slope protection material.
- Disintegration or breakdown of material.
- Tearing of geotextiles.
- Corroded or broken wire mesh.

4.2.2 PERFORMANCE DEFECTS OF SLOPE PROTECTIONS

Performance defects in slope protections are related to their ability to protect the embankments and stream banks from erosion or scour and are reflected in the movements of slope protection systems.

Movements of slope protections may consist of:
- settlement of the slope protection;
- sliding of the slope protection.

Movements of slope protections may be caused by:
- movements of the embankments or the stream banks;
- material defects of the slope protection systems.

Type		Material Composition	Remarks
1	Organic	Grass, Brush, etc.	Used where large run-off is not expected.
2	Rip-Rap	Stones, Rubble.	Random, hand-laid or grouted. Commonly used in streams.
3	Granular	Crushed stone or gravel.	Commonly used at grade separations
4	Cast-in-Place Concrete	Reinforced concrete slab, 100 mm to 150 mm thick, divided into panels.	Commonly used at grade separations
5	Precast Concrete	Interlocking slabs or elements.	Elements placed on permeable base which permits some seepage between elements.
6	Bituminous	Asphaltic concrete	Compacted.
7	Wire Baskets	Wire mesh baskets filled with stones.	Commonly used near streams.
8	Bag Mortar	Premixed concrete bags stacked on each other.	Hand placed and allowed to set in place.
9	Geotextiles	Inorganic fabrics which allow penetration of water but not soil.	Normally used under other tiles protections to prevent washing away of fines by subgrade seepage.

Table 4.2 Slope Protection Systems

SECTION 5 - SUBSTRUCTURES

Contents

5.1 SUBSTRUCTURES

The following components are to be considered as substructures:

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

5.1.1 FOUNDATIONS

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

(a) Shallow Foundations

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

Shallow foundations are normally made of mass concrete, reinforced concrete, wood or masonry. They are occasionally made of reinforced earth, gabions or cribs filled with stones or earth.

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

Typical examples of shallow foundations are shown in Figure 5.1.1(a).

(b) Deep Foundations

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

Commonly used piles are steel H piles, steel tube piles, timber piles, and reinforced or prestressed concrete piles. Caissons are normally made of large diameter tube piles or box sections made of concrete, steel sheet piles or H piles. They are sunk through ground or water for the purpose of placing the foundation at the prescribed depth and, subsequently, become part of the foundation. Steel tubes and caissons may be filled with concrete.

Piles or caissons may terminate with or without a footing, which may be located below ground or water level. Where piles or caissons extend to the level of the superstructure they should be inspected as piers or abutments as appropriate.

Typical examples of deep foundations are shown in Figure 5.1.1(b).

5.1.2 ABUTMENTS

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

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

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

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

Typical examples of abutments are shown in Figure 5.1.2(a). Examples of structures without abutments are shown in Figure 5.1.2(b).

5.1.3 PIERS

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

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

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

Typical examples of piers are shown in Figure 5.1.3.

5.1.4 RETAINING WALLS

Retaining walls consist of walls with or without foundations.

Retaining walls are commonly made of mass concrete, reinforced concrete, wood. Occasionally, masonry, steel piles, precast concrete, wire baskets, bag mortar and reinforced earth have been used for their construction. They can be categorized as follows based on their design:

Gravity Retaining Walls - mass concrete, masonry, timber cribs, concrete cribs, steel cribs, wire baskets and bag mortar.

Cantilever Retaining Walls - reinforced concrete, steel sheet piling, post and lagging (concrete, wood or steel or a combination of these).

Anchored Retaining Walls - Reinforced earth and tie-back walls.

Typical examples of gravity, cantilevered and anchored retaining walls are shown in Figures 5.1.4(a), (b) and (c) respectively.

5.2 PRIMARY COMPONENTS

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

5.2.1 MATERIAL DEFECTS OF PRIMARY COMPONENTS

Material defects are as given in Section 2.

5.2.2 PERFORMANCE DEFECTS OF PRIMARY COMPONENTS

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

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

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

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

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

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

5.3 SECONDARY COMPONENTS

Ballast walls, wingwalls, retaining walls and bearing seats are to be considered as secondary components. The foundations of wingwalls and retaining walls are also to be considered as secondary components.

5.3.1 MATERIAL DEFECTS OF SECONDARY COMPONENTS

Material defects are as given in Section 2.

5.3.2 PERFORMANCE DEFECTS OF SECONDARY COMPONENTS

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

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

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

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

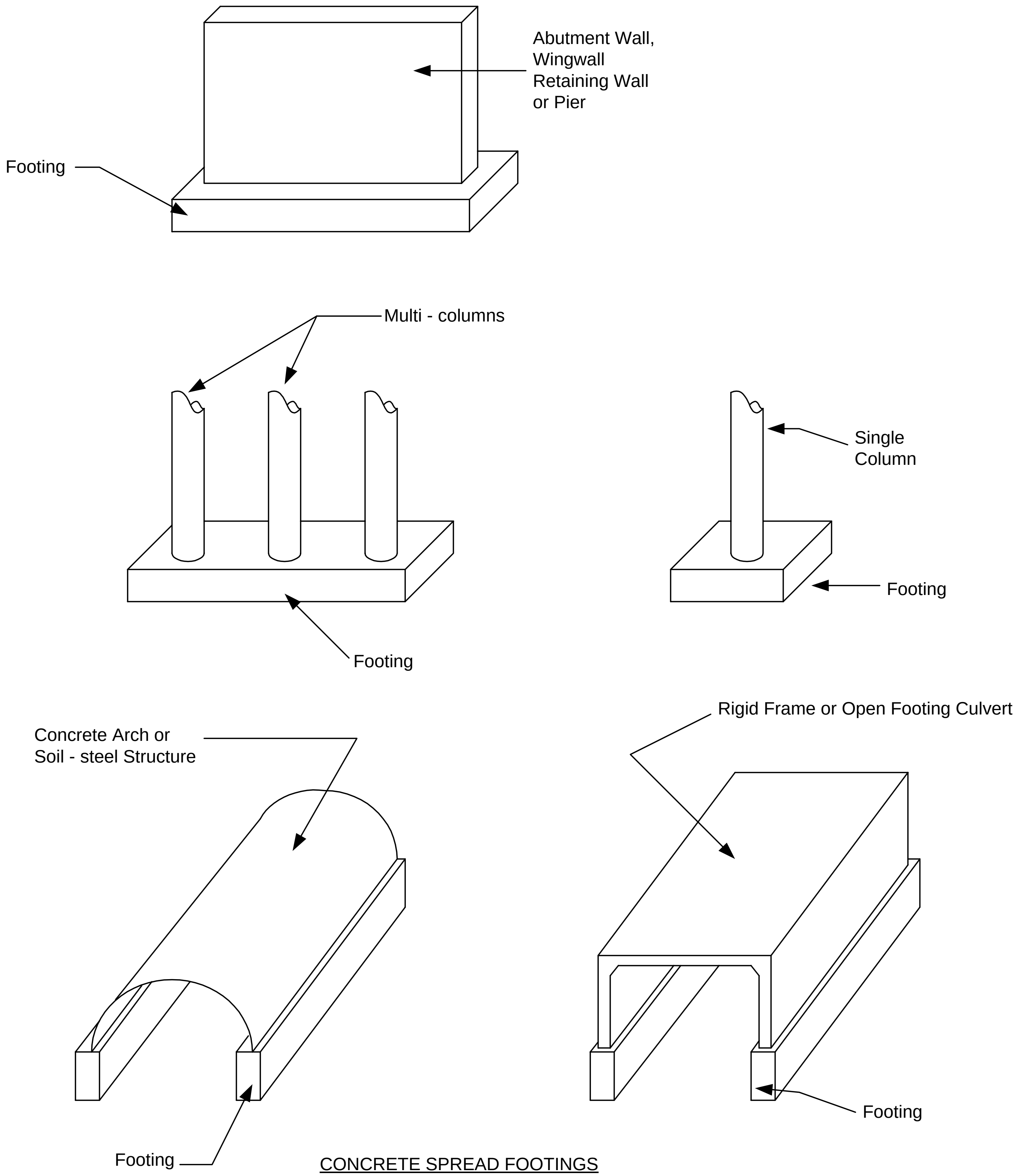
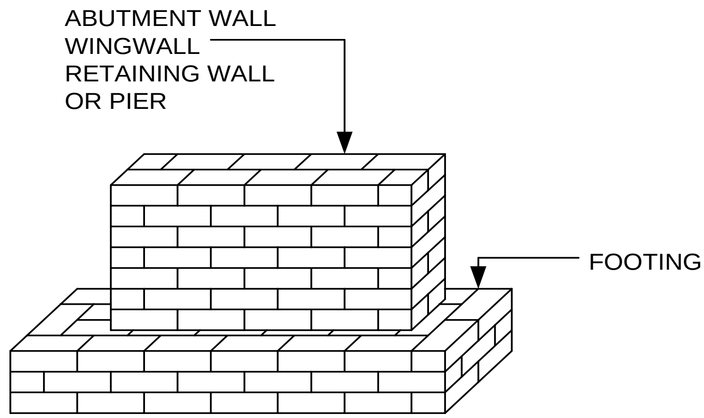
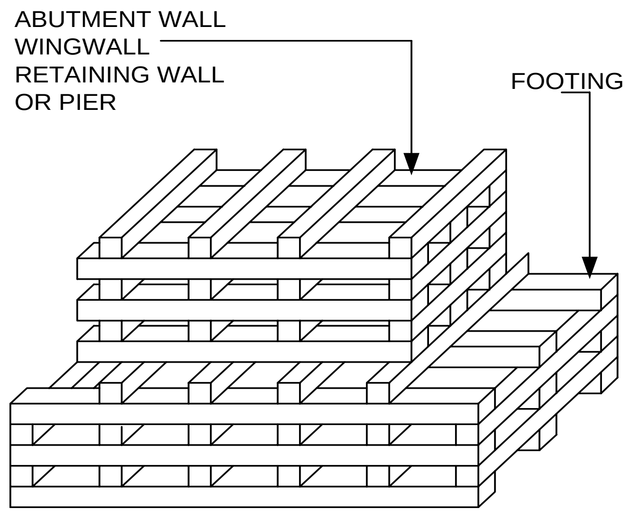


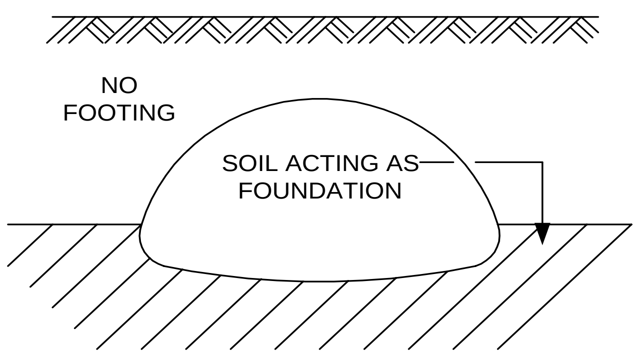
Figure 5.1.1(a) Typical Shallow Foundations



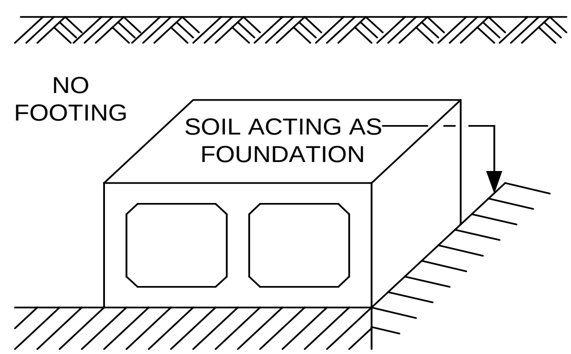
MASONRY FOOTING



WOOD CRIB FOOTING



SOIL STEEL STRUCTURE



BOX CULVERTS

Figure 5.1.1(a) Typical Shallow Foundations (Continued)

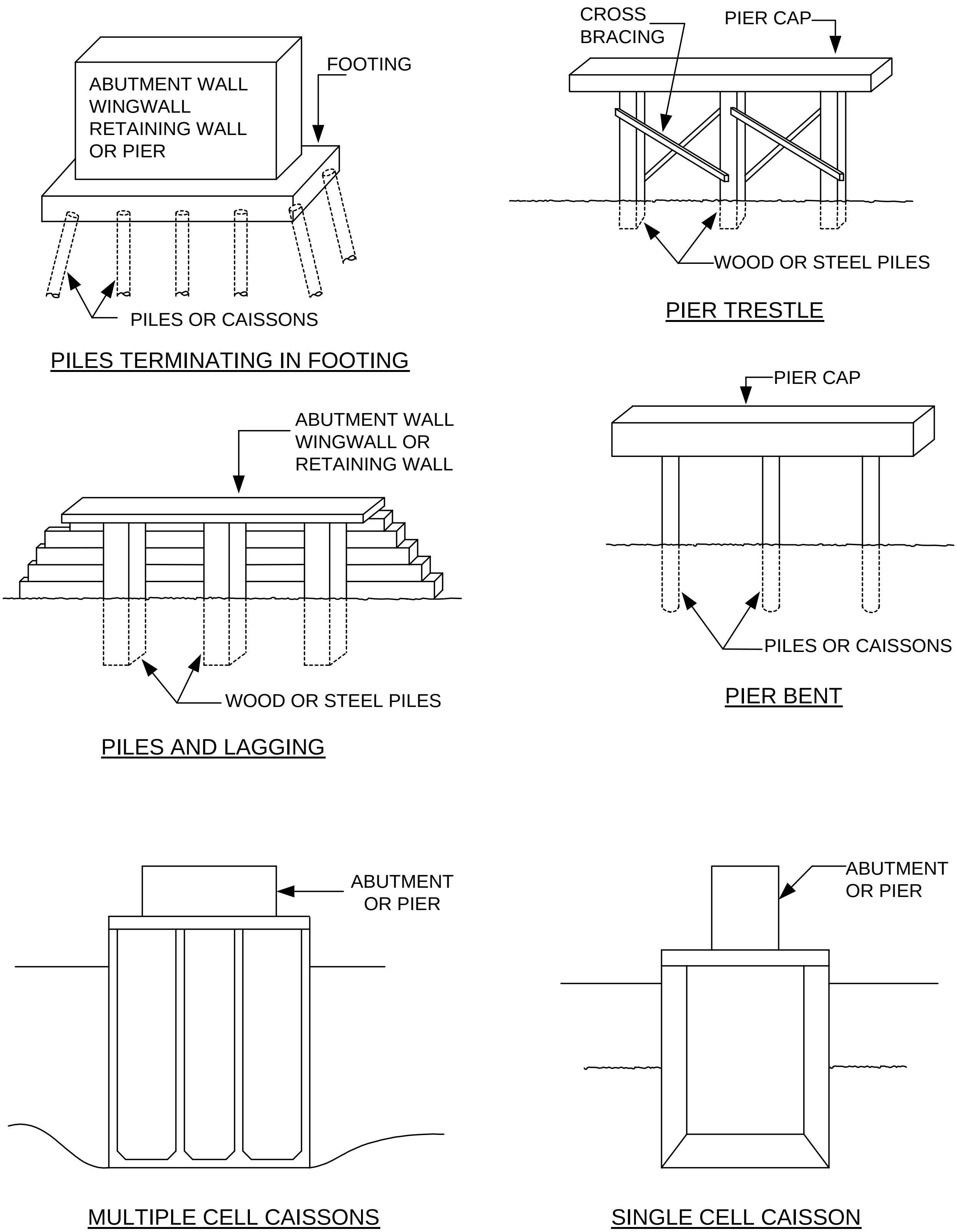


Figure 5.1.1(b) Typical Deep Foundations

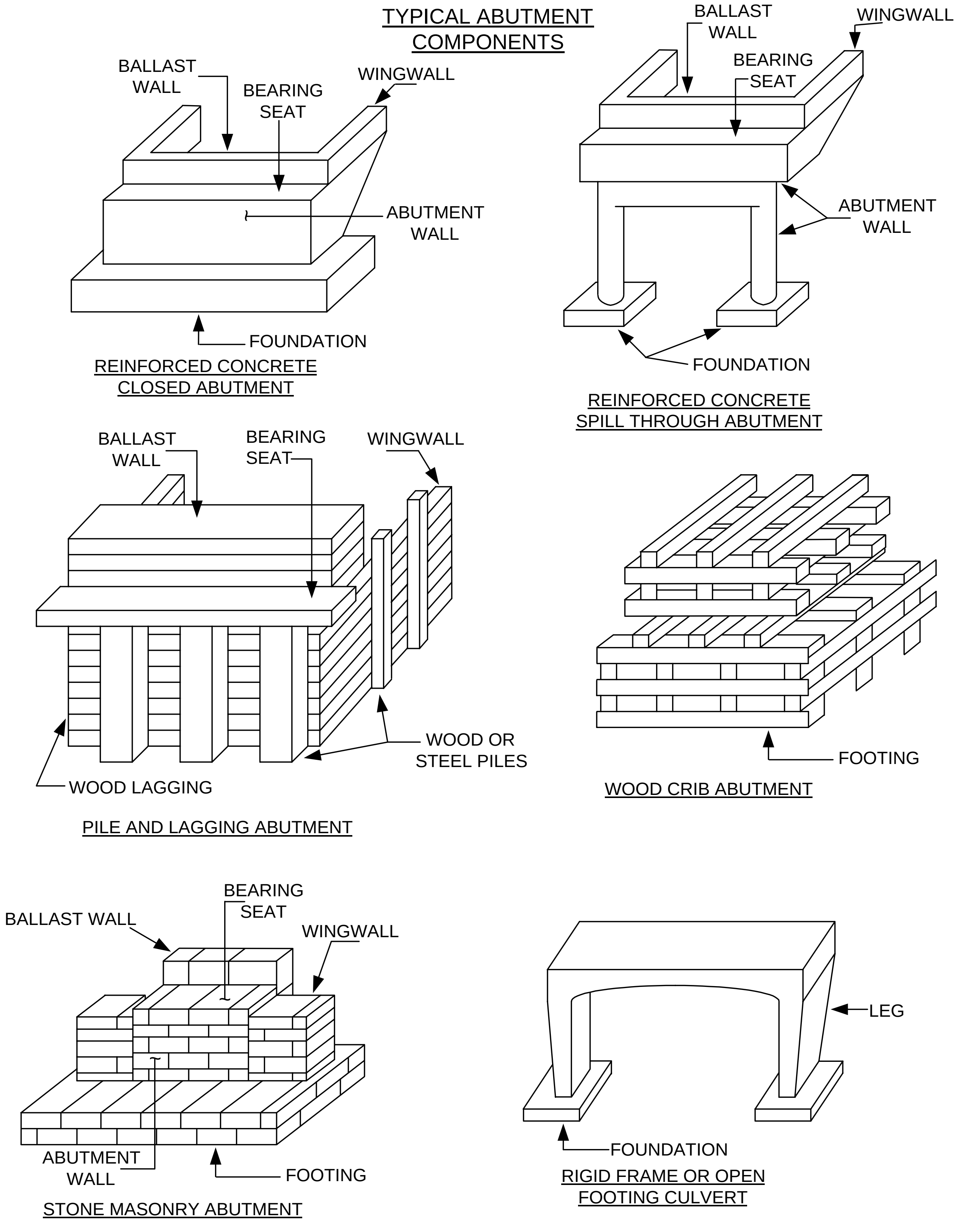
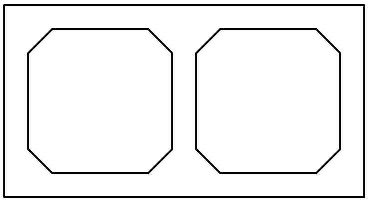
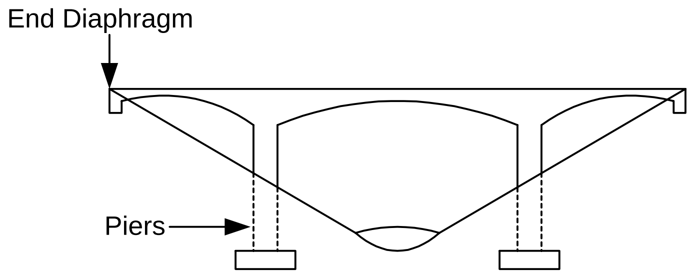


Figure 5.1.2(a) Typical Abutment Components



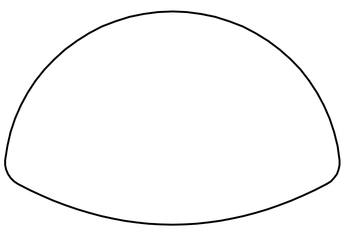
No Abutment

BOX CULVERTS



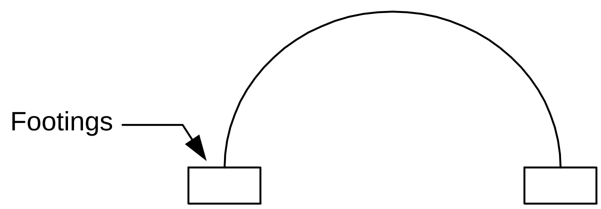
No Abutment

CANTILEVERED END SPANS



No Abutment

SOIL STEEL STRUCRURE



No Abutment

CONC. OR SOIL STEEL STRUCTURE

Figure 5.1.2(b) Structures Without Abutments

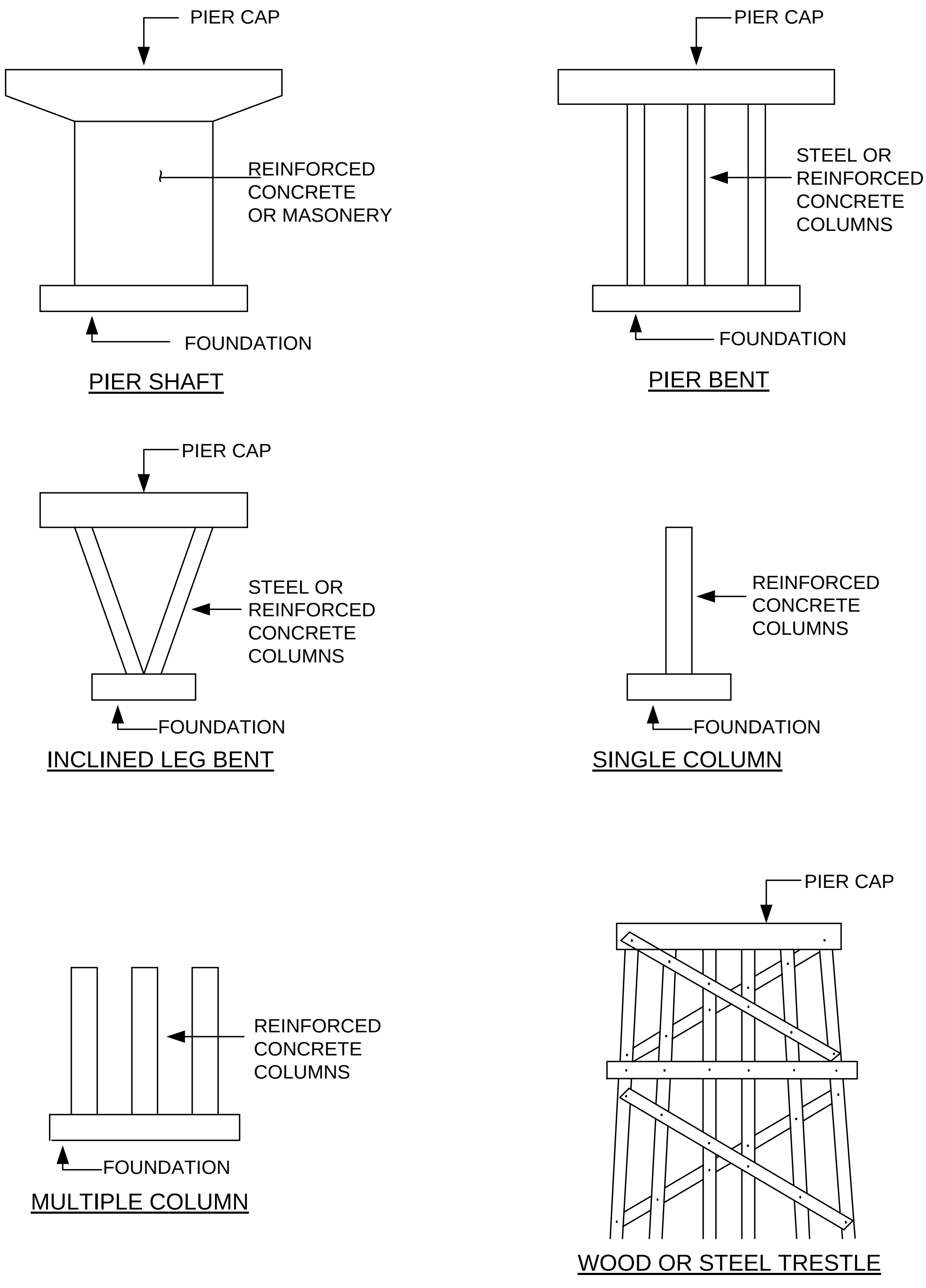
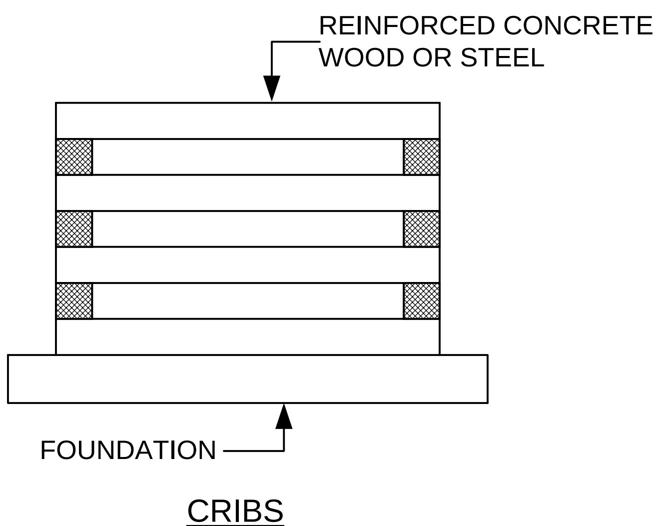


Figure 5.1.3 Typical Piers



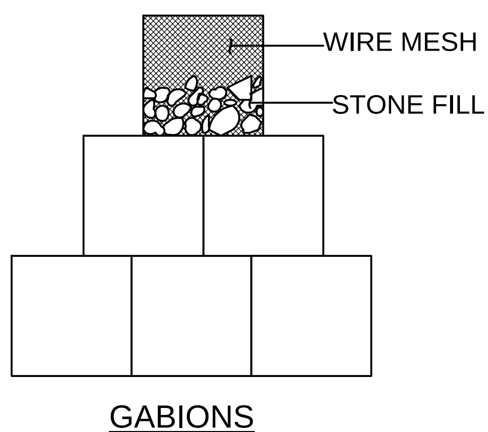


Figure 5.1.3 Typical Piers (continued)

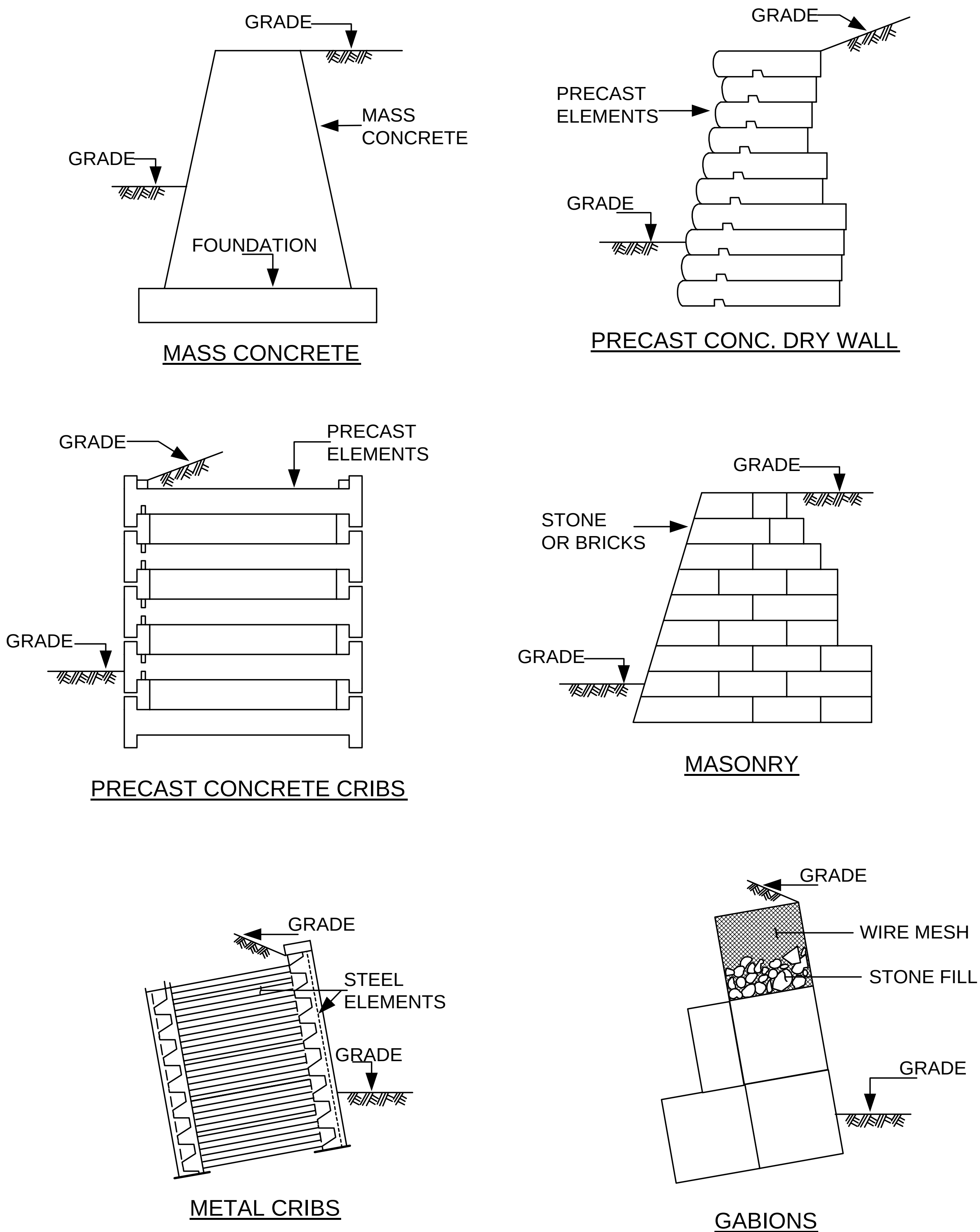
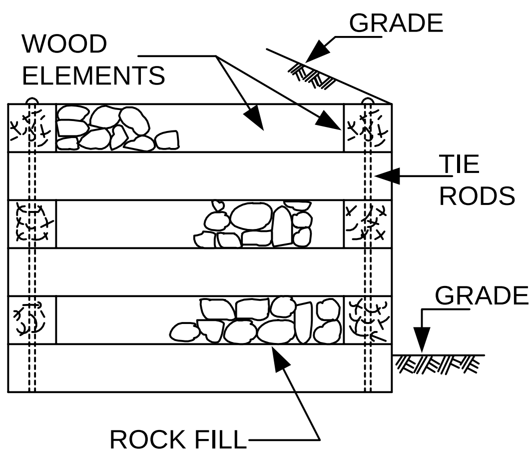
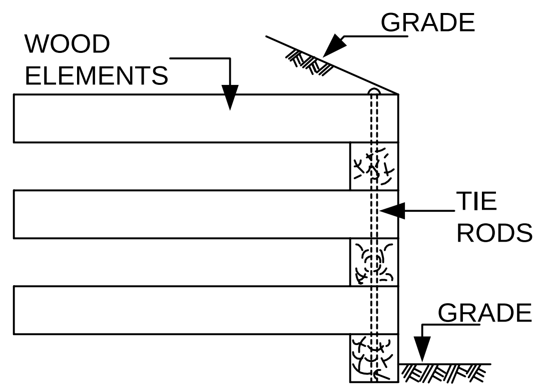


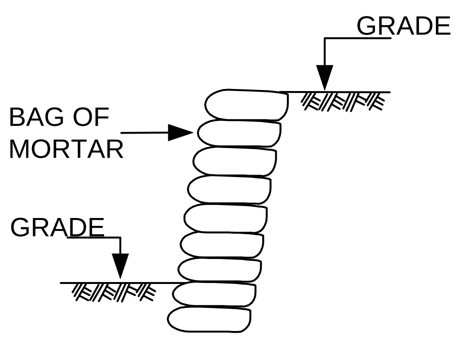
Figure 5.1.4(a) Typical Gravity Retaining Walls



WOOD CRIB

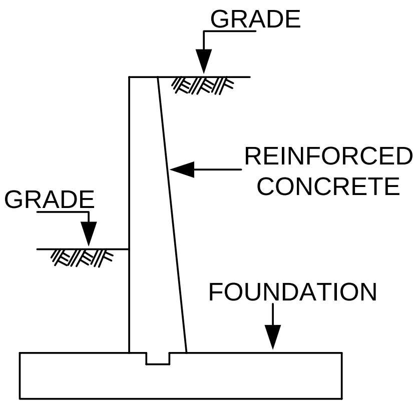


WOOD DRY WALL

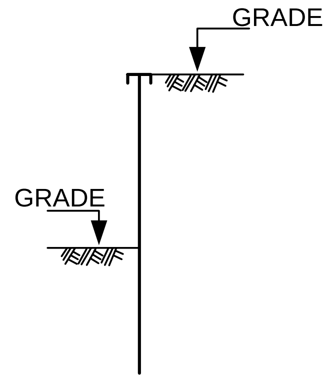


BAG MORTAR

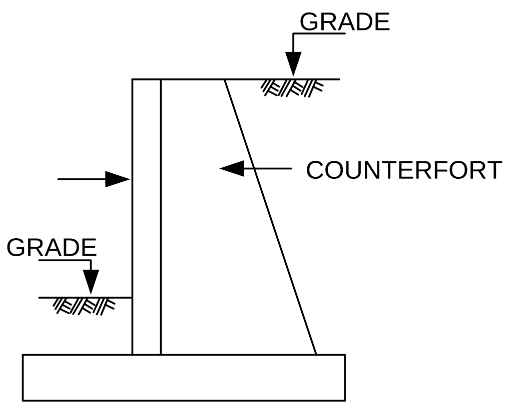
Figure 5.1.4(a) Typical Gravity Retaining Walls (Continued)



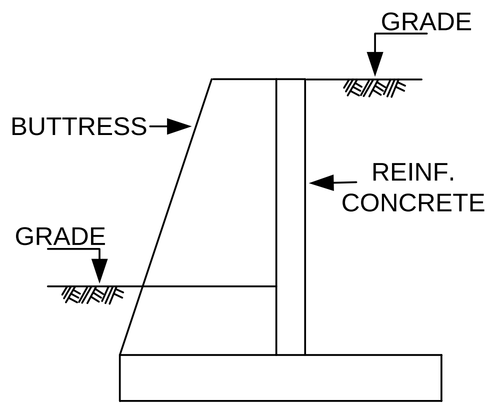
REINFORCED CONCRETE



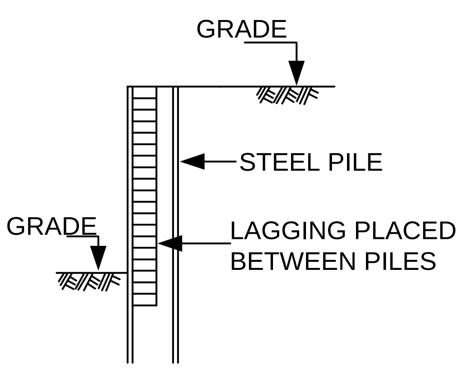
SHEET PILES



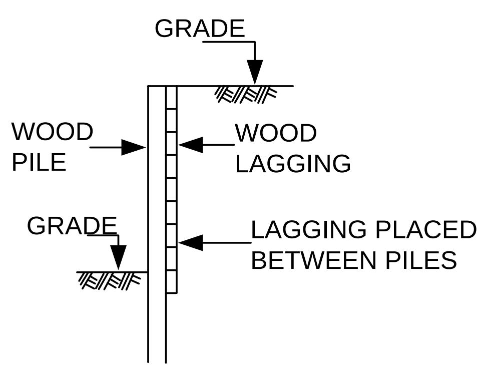
REINFORCED CONCRETE
COUNTERFORT WALL



REINFORCED CONCRETE
BUTTRESS WALL

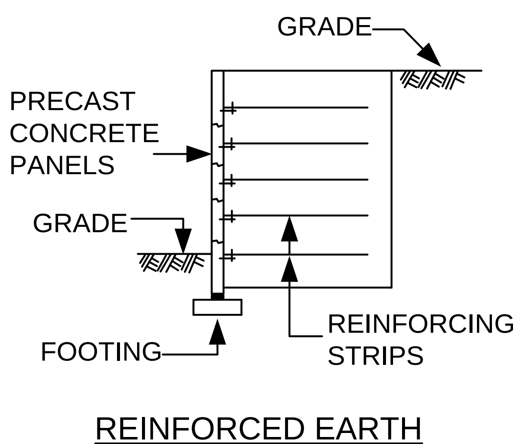


STEEL PILES AND LAGGING



STEEL PILES AND LAGGING

Figure 5.1.4(b) Typical Cantilever Retaining Walls



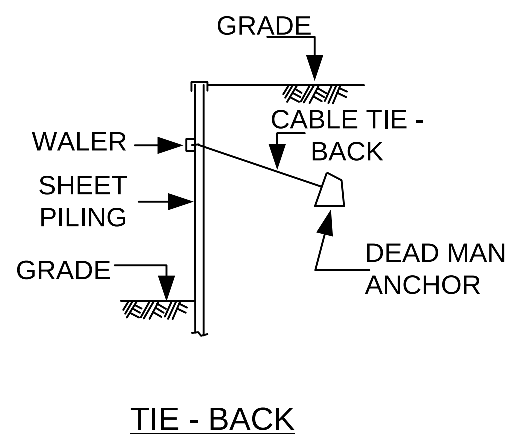


Figure 5.1.4(c) Typical Anchored Retaining Walls

SECTION 6 - BEARINGS

Contents

6.1 BEARINGS

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

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

There are numerous types of bearings made of various materials that have been used in bridges over the years. Bearings usually consist of a number of parts which may include the following, but not all bearings would have these and some may have other parts as well.

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

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

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

Bearings are grouped as follows and are illustrated in Figure 6.1(a) to 6.1(g).

(a) Steel Plate Bearings

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

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

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

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

(b) Elastomeric Bearings

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

Fixity is provided by pins or anchor bolts;

Translation is provided by the pad;

Rotation is provided by compression of the pad.

(c) Pot and Disc Bearings

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

Fixity is provided by anchor bolts or pins;

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

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

(d) Spherical and Cylindrical Bearings

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

Fixity is provided by anchor bolts or pins;

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

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

(e) Rocker Bearings

Rocker bearings provide both translation and rotation.

Fixity is provided by anchor bolts or pins;

Translation is provided by tilting or rotation of the rocker;

Rotation is provided by curved top or bottom surfaces.

(f) Roller Bearings

Roller bearings provide translation. They may also provide rotation.

Fixity is provided by anchor bolts or pins;

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

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

(g) Pin and Hanger Bearings

Pin and hanger bearings provide both translation and rotation.

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

Rotation is provided by rotation about the pins.

6.1.1 MATERIAL DEFECTS OF BEARINGS

Material defects in bearings, in addition to those given in Section 2, are:

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

6.1.2 PERFORMANCE DEFECTS OF BEARINGS

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

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

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

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

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

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

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

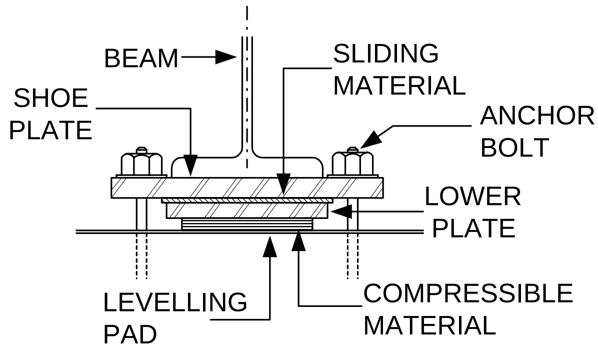


Figure 6.1(a)- Steel Plate Bearing

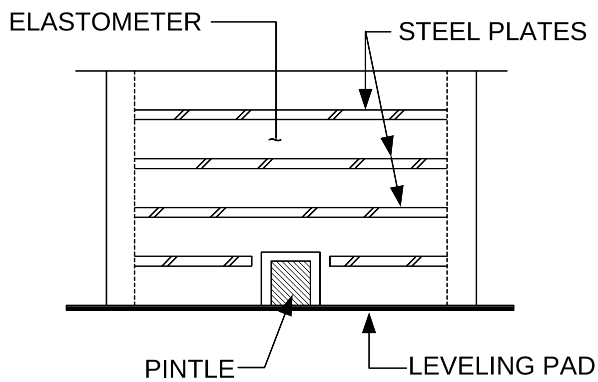
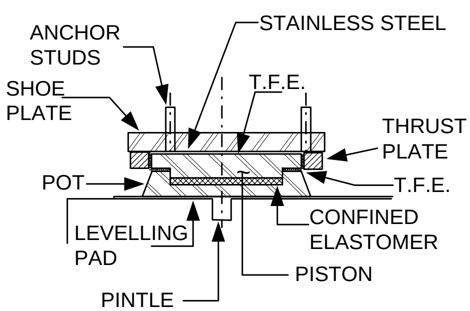
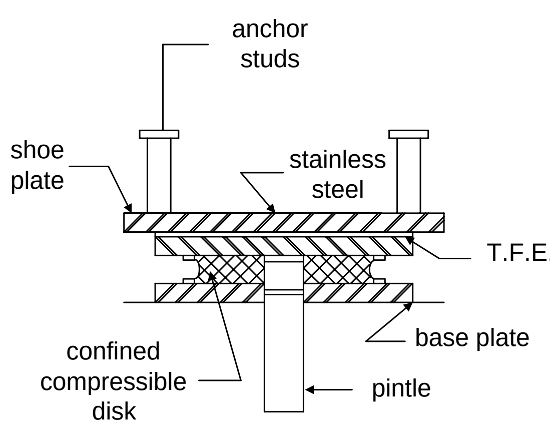


Figure 6.1(b) - Elastomeric Bearing



Expansion Pot Bearing



Multi-Directional Disk Bearing

Figure 6.1(c) - Pot or Disc Bearing

Figure 6.1 Typical Types of Bearings

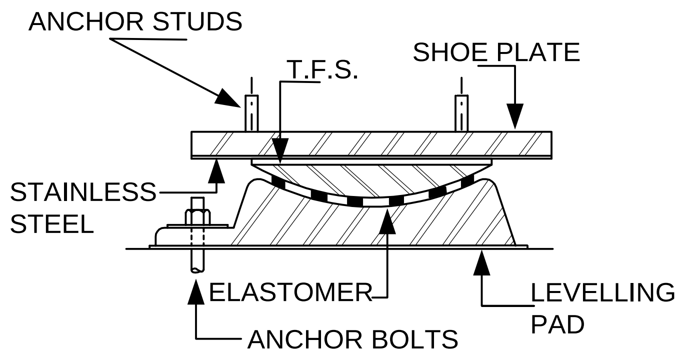
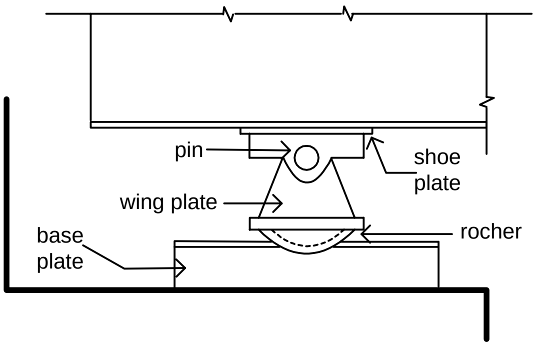
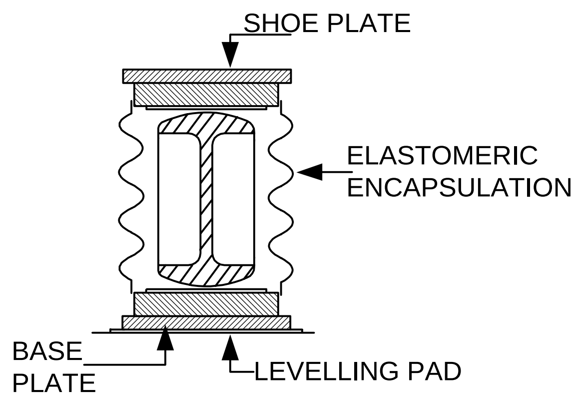


Figure 6.1(d) - Spherical Bearing



Steel Rocker Bearing



Rocker Bearing

Figure 6.1(e) - Steel Rocker Bearing

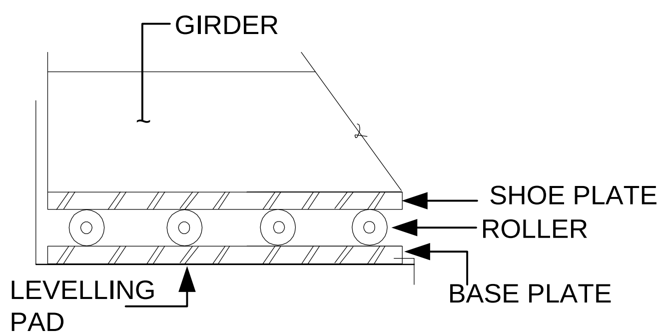


Figure 6.1(f) - Expansion Roller Bearing

Figure 6.1 Typical Types of Bearings (cont'd)

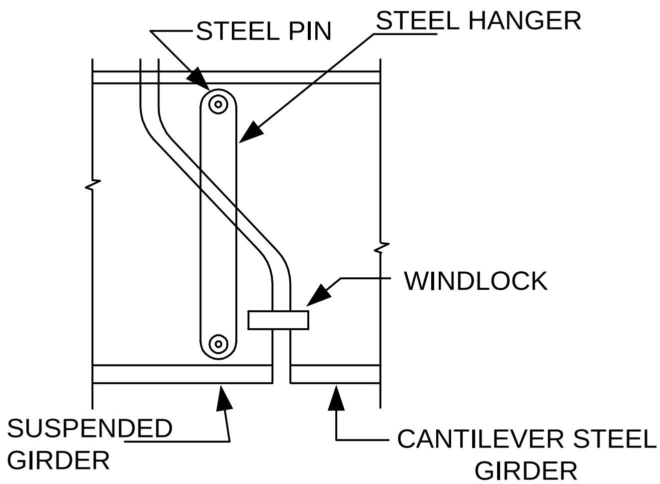


Figure 6.1(g) - Pin and Hanger Bearing

Figure 6.1 Typical Types of Bearings (cont'd)

Contents

7.1 JOINTS

Joints in decks may occur between the deck and the abutment, over the piers between adjacent spans, or within the span at suspended spans.

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

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

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

Types of joints commonly used in structures are described below and illustrated in Figures 7.1(a) to 7.1(f).

(a) Open Joints

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

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

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

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

(b) Poured-In-Place Joints

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

Hot or cold poured bituminous or mastic asphalt joints consist of an inert filler placed in the joint gap to below the level of the finished grade, and a hot or cold poured bituminous or mastic asphalt sealant filling the remaining gap to the finished grade. It may be used with asphalt or concrete pavements.

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

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

(c) Compression Seal Joints

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

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

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

(d) Elastomeric Cushion Joints

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

(e) Multiple Seal (Modular) Joints

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

(f) Strip Seal Joints

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

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

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

7.1.1 MATERIAL DEFECTS OF JOINTS

Material defects of joints in addition to those given in Section 2 are:

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

7.1.2 PERFORMANCE DEFECTS OF JOINTS

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

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

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

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

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

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

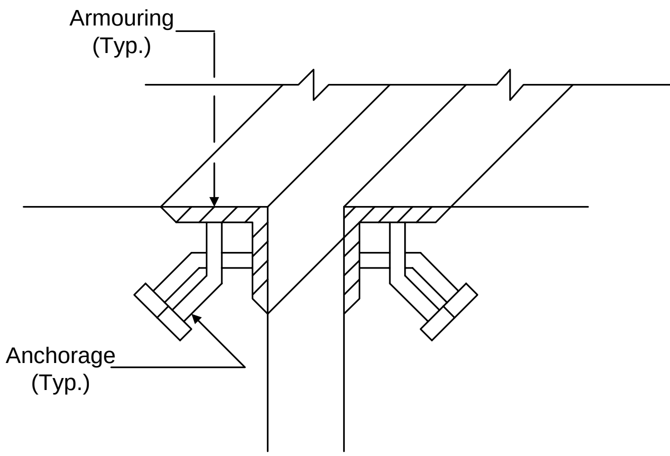
An incorrect joint gap is likely a symptom of improper functioning of the bearings, or of movements of the abutments, pier or foundation. The inspector shall measure and record the joint gap and air temperature at the time of inspection.

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

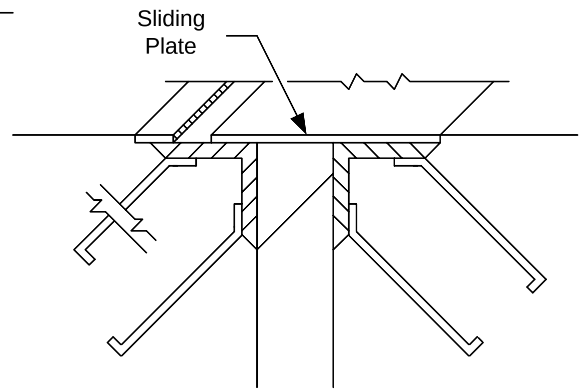
Vertical misalignment can result in a bumpy ride across the joint and a potential hazard of loss of vehicle control. Vertically misaligned joints are also subject to damage by snow-plows.

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

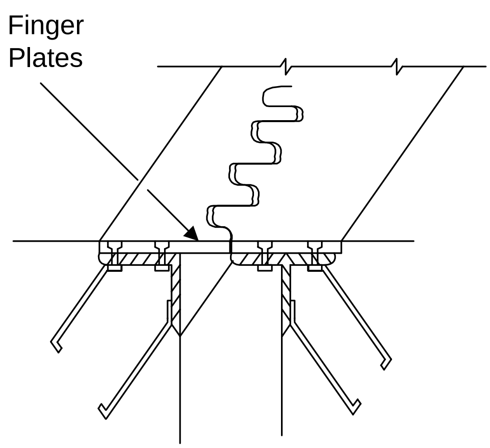
The performance of joints as regards watertightness, in the case of sealed joints, is based upon the extent of leakage of roadway drainage through the joint. Joint leakage can result in serious deterioration of the joint materials and other structure components located below the joint.



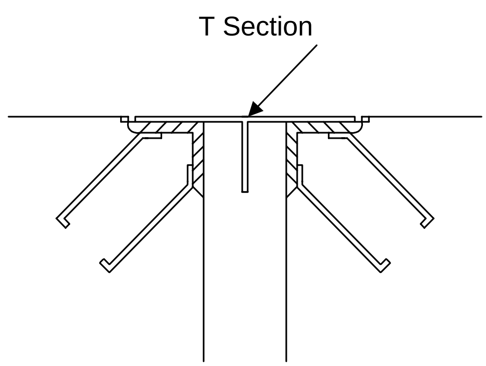
Open Gap Joint



Sliding Plate Joint



Finger Plate Joint



Drop-in-T Joint

Figure 7.1(a) Open Joints

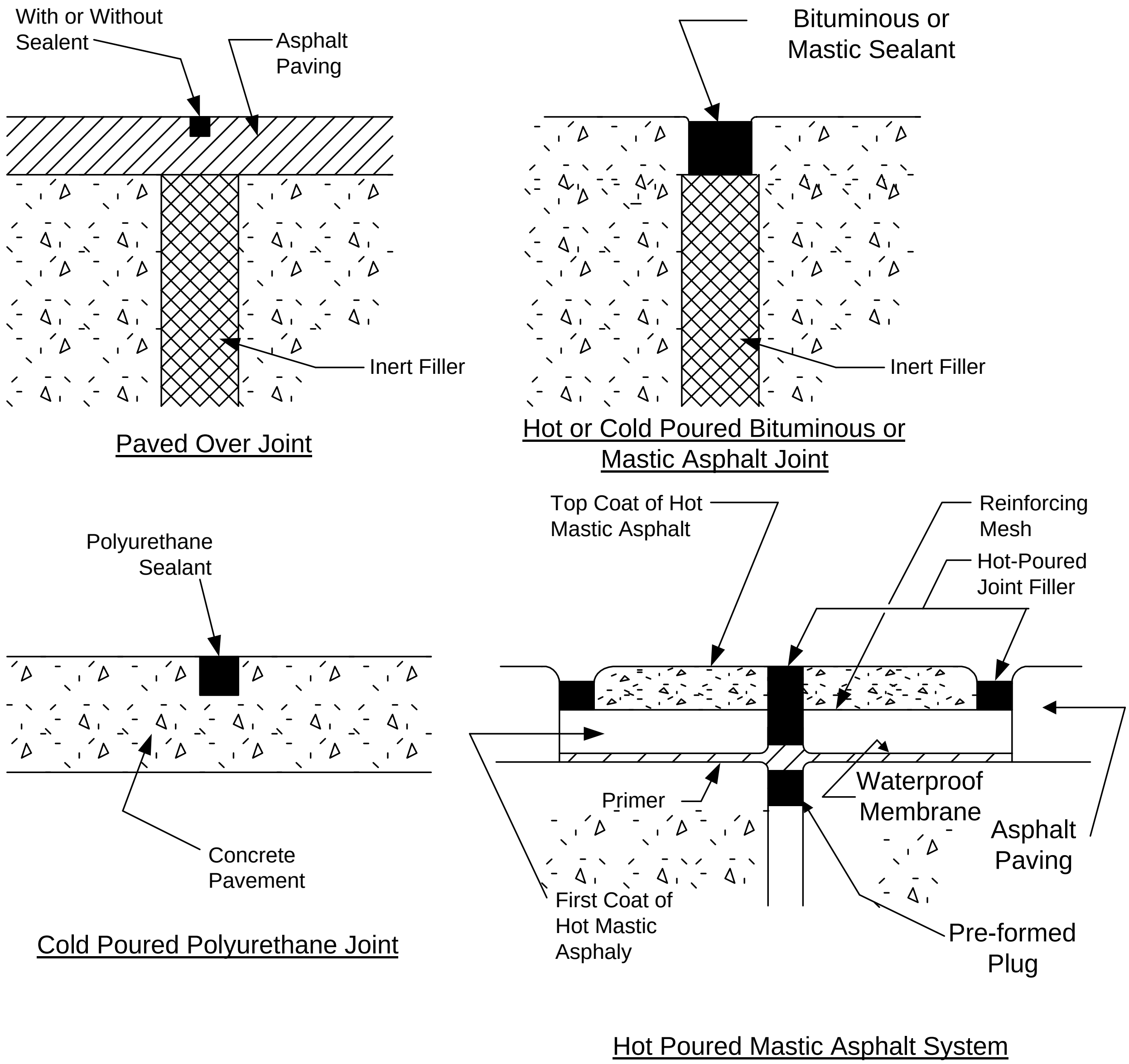


Figure 7.1(b) Poured-In-Place Joints

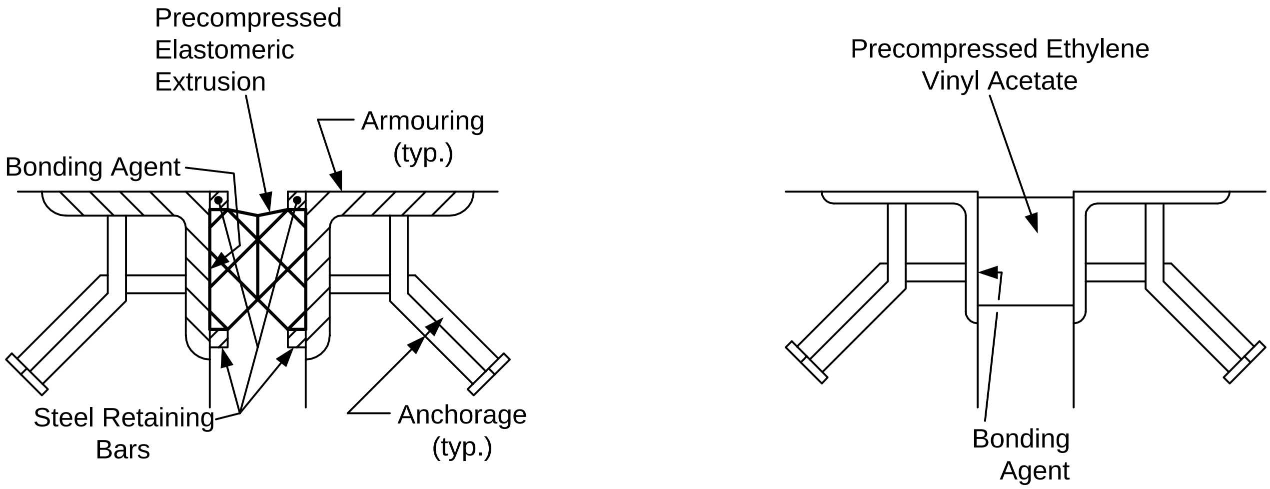


Figure 7.1(c) Compression Seal Joints

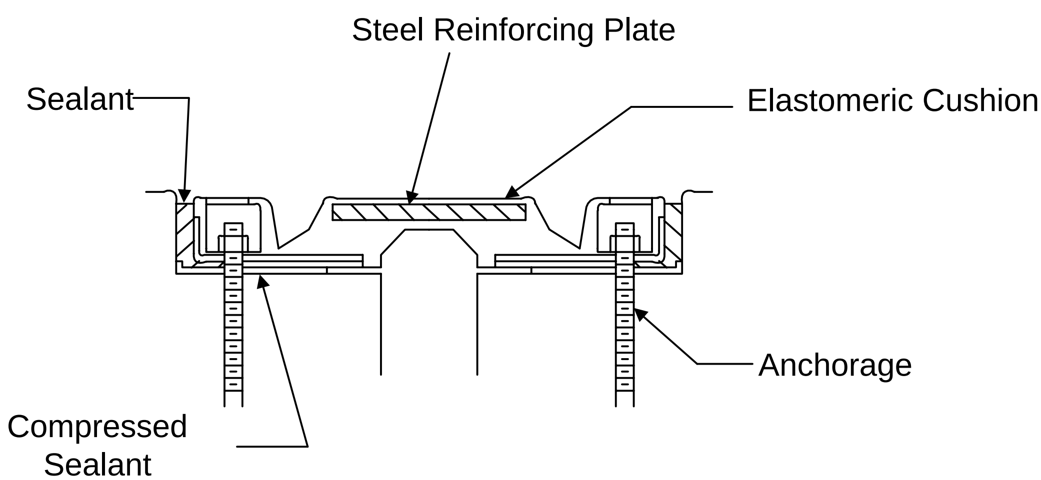


Figure 7.1(d) Elastomeric Cushion Joints

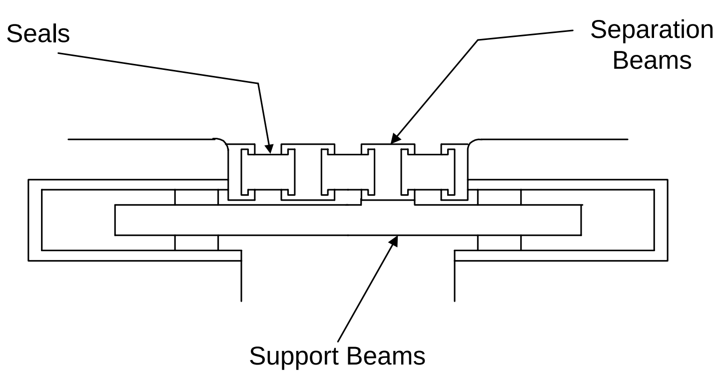


Figure 7.1(e) Multi-Seal Joints

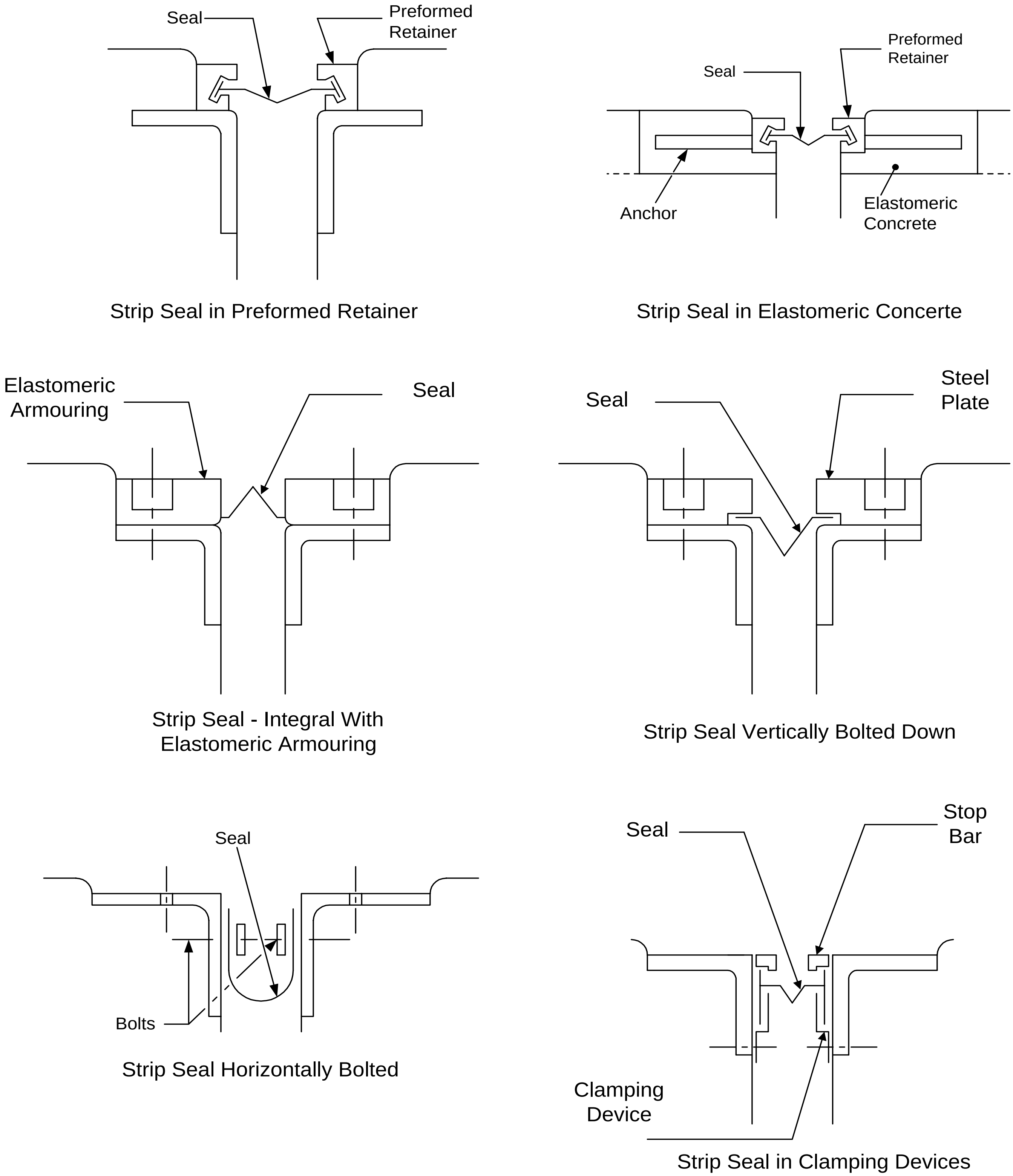


Figure 7.1(f) Strip Seal Joints

SECTION 8 - SUPERSTRUCTURES

Contents

8.1 SUPERSTRUCTURES

Superstructures normally consist of all components of structures supported on the substructures. The following components of superstructures are covered in this section:

- Beams and girders;
- Thick slabs;
- Trusses;
- Arches;
- Culverts;
- Soil Steel Structures;
- Movable bridges in fixed position;
- Suspension bridges;
- Stringers and floor beams under the decks;
- Diaphragms;
- Sway bracings;
- Lateral bracings;

Other parts of the superstructure, such as, decks, curbs, sidewalks, parapet walls, railings and expansion joints are covered in other sections of OSIM.

Movable bridges shall be inspected and recorded by the type of the main load carrying components. Inspection of mechanical or electrical parts of movable bridges is not covered in OSIM.

8.1.1 BEAMS AND GIRDERS

Beams and girders are made of reinforced or prestressed concrete, steel or wood.

Beams and girders may be simply supported, semi-continuous for live and superimposed dead loads, continuous over a number of spans or cantilevered beyond the support with a drop-in section added to complete the span.

Concrete beams or girders are cast-in-place or precast as one unit or in segments. They may be T-shape, rectangular or trapezoidal in shape and may have single or multiple voids of various shapes in them.

Steel beams or girders are rolled into standard shapes or built-up into I-shape, rectangular or trapezoidal boxes by riveting, bolting or welding. They may be unstiffened or stiffened with vertical or longitudinal stiffeners. They may be erected as single units or in segments.

Wood beams or girders may be sawn, laminated or glued and are, normally, rectangular in shape. They are erected as single units but may sometimes be spliced together with steel plates, fasteners or gang-nail plates.

Beams and girders support decks directly on them except in the case of half-through girders in which the load from the deck is first transferred to stringers and floor beams and then to the girders.

Beams and girders may have diaphragms and lateral bracings between them. Concrete girders, normally, have solid concrete diaphragms whereas steel girders may have diaphragms made of steel beams, girders, channels or angles. Steel girders may also have lateral bracings made of steel angles or channels.

Beams and girders carry loads by flexural, shear or torsional resistance. Examples of typical beams and girders are illustrated in Figure 8.1.1.

8.1.2 THICK SLABS

Thick slabs are made of reinforced or prestressed concrete or a combination of these.

They may be simply supported or continuous.

They may be solid or contain round, rectangular or trapezoidal voids, and are normally cast-in-place. The deck slabs of rigid frames are to be considered as thick slabs.

The top surface of thick slabs acts as the deck and shall be inspected as detailed in Section 9.

Thick slabs carry loads by flexural, shear, torsion and axial forces depending on the fixity and configuration of the support systems. Examples of thick slabs used are illustrated in Figure 8.1.2.

8.1.3 TRUSSES

Trusses are made of steel or wood. A few trusses made of cast iron are still in existence.

Trusses may be single or multiple span and may be simply supported or continuous. They may also be cantilevered beyond the support with a 'drop-in' truss section to complete the span.

Trusses consist of top and bottom chords, verticals and diagonals.

Types of trusses commonly encountered are the through truss, half-through (pony) truss, deck truss and the bailey bridge truss.

Through trusses are connected together across the top chords above the roadway level by transverse portals, sway frames and lateral bracings. The bottom chords are connected together below the roadway level by transverse floor beams which support longitudinal stringers and the deck. The bottom chords are also connected by lateral bracings below the deck.

Half-through trusses are not connected across the top chords allowing for unrestricted overhead clearance. Sway braces or rakers are connected between the top chords and floor beams, or needle beams, to provide lateral restraint to the top chord. The bottom chords are connected together below the roadway level by transverse floor beams which support longitudinal stringers and the deck. The bottom chords are also connected by lateral bracings below the deck.

Deck trusses are located entirely below the roadway level. They may directly support the deck, or the deck may be supported on longitudinal stringers and transverse floor beams resting on the deck trusses. Adjacent trusses are also commonly connected by transverse cross bracing between the top and bottom chords, and by additional lateral bracing between the bottom chords.

Bailey bridge trusses are built of components that can be erected into a number of different types of trusses. The most common being the half-through type. Sway bracings, lateral bracings and floor systems for the bailey bridges are similar to the half-through trusses described above.

Components of steel trusses consist of individual rolled sections or are built-up by bolting, riveting or welding several sections together. Older steel trusses may contain solid round or square bars or eye-bars, while more recent steel trusses may also contain tubular sections. Components of wood trusses are typically made from solid rough-sawn sections or are built-up by bolting or gluing several sections together. Steel rods are also often used for tension components in wood trusses.

Individual truss components are connected together at joints with splice plates or gusset plates fastened by pins, rivets, bolts, lag-screws, nails or by welding.

While their overall configuration may vary, trusses are built up of individual components interconnected in triangular arrangements in such a manner that the components resist applied loads axially, through compression or tension.

However, depending on the degree of fixity, either actual or assumed, at the connections, and on the location of the applied load on the member, some of the truss components may also be subject to flexural, shear or torsional loads. Trusses and common terminology used to describe their components are illustrated in Figure 8.1.3(a).

Typical bailey bridge configurations and components are shown in Figures 8.1.3(b) and (c). For a complete coverage of bailey bridges see reference (1).

8.1.4 ARCHES

Arches are made of concrete, steel, wood or masonry.

Arches may be single or multiple span and may be hinged or fixed at the supports. They may have an intermediate hinge at their crown.

Arches consist of arch ribs, top or bottom chords, verticals and diagonals.

Types of arches commonly encountered are the tied (bowstring) arch, through arch, open spandrel arch, filled spandrel arch and barrel arch.

Tied (Bowstring) arches are used where the soil is not capable of resisting the horizontal thrust of the arch rib. The bottom chord, or tie, may also support the deck system as they are usually at the same level. There may also be a system of portal or sway frames and lateral bracing between the arch ribs over the roadway. In steel tied arches there may also be a system of lateral bracing under the deck.

Through arches are used where the soil is capable of resisting the horizontal thrust of the arch. In this arch, the deck and floor system is suspended from the arch rib by hangers. The arch ribs are also connected together across the top by a system of portal and sway frames and lateral bracing. There may also be a system of lateral bracing under the deck.

Open spandrel arches are used where the soil is capable of resisting the arch thrust. In this type of arch the deck is located above the level of the arch crown, and the deck and floor system is supported on columns carried down to the arch rib(s).

In steel spandrel arches there are two or more parallel ribs interconnected by a bracing system. Concrete spandrel arches may have several ribs interconnected with diaphragms, but are also commonly built with only one solid arch, the full width of the deck.

Filled spandrel arches are commonly used for short spans, and is usually fixed ended. The arch is backfilled with earth, granular or other suitable fill which forms the base for the deck. The sides of this arch are closed by retaining walls and wingwalls.

Barrel arches are similar to the filled spandrel arches except that the sides are open and therefore there are no retaining walls.

Components of steel arches consist of individual rolled sections or are built-up by bolting, riveting or welding several sections together. Older steel arches may contain solid round or square bars or eye-bars, while more recent steel arches may also contain tubular sections.

In steel arches, the components are connected together at joints with splice plates or gusset plates fastened by pins, rivets, bolts or by welding. In comparison, concrete arches are usually constructed monolithically with the deck system, ties, railings, hangers, and arch rib rigidly connected so that interaction and stress distribution among the components is extremely complex.

While their overall configuration may vary, the arrangement and connection of their components and the degree of fixity at the supports and between the connections determine the distribution of applied loads internally in the arch and the transfer of load to the foundation or soil. The arch ribs resist applied loads mainly by compression and flexure. The arch ties resist loads mainly by tension and some flexure depending on the location of the applied loads.

Concrete arches are usually monolithically cast, with the result that the interaction and stress distribution among the components is extremely complex. Also, when the arches have fixed ends they are very sensitive to differential settlement or rotation of the foundation, which may produce overstressing and cracking locally.

Arches and the common terminology used to describe them are illustrated in Figures 8.1.4.

8.1.5 CULVERTS, TUNNELS AND SOIL-STEEL STRUCTURES

Culverts and soil-steel structures are bridges embedded in fill. In most cases, they convey water through an embankment; however, occasionally they provide access to pedestrian, rail or vehicular traffic through the embankment.

A tunnel is a bridge constructed through existing ground. In most cases it provides access to pedestrian, rail or vehicular traffic. Occasionally, it is designed to convey water.

Culverts and tunnels may be made of concrete or wood. Soil- steel structures are comprised of corrugated steel pipe or plates, and soil, designed and constructed to induce a beneficial action between the structure and the soil. Soil-steel structures are constructed in several shapes; namely, round, ellipses, pipe arches, superspans and with or without ears or relieving slab.

High embankments or fills may impose very large vertical and lateral earth loads on culverts and tunnels which can result in structural failure of the roof, floor slab or walls.

The strength of a soil-steel structure is derived from the interaction between the structure and the surrounding soil. Vertical loads from the overlying soil and traffic are transmitted by arching action to the underlying soil. If the side support is not provided due to inadequate placement, compaction or loss of soil or backfill material; then, failure of the structure can result.

Culverts, tunnels and soil-steel structures are divided into two main types according to cross-section; namely, open invert and closed invert. An open invert structure has a floor of natural soil, bedrock or other material that is not structurally integral with the walls. A closed invert structure is one where the floor is structurally integral with the walls.

Where these structures are used to carry water their basic components can be divided into inlet, barrel and outlet as shown in Figure 8.1.5(a). The inlet channels water into the barrel and the outlet channels the water back into the stream. The inlet and the outlet may also contain headwalls, cut-off walls, wingwalls, headerwalls and aprons to provide protection against scour and piping. The barrel and outlet may also contain drop-outlets, stilling basins, chutes and stepped flumes to dissipate the energy of the water before it re-enters the stream, as shown in Figure 8.1.5(b).

When a roadway is widened or when the road grade is raised, extensions to these structures may be built using different materials. It is necessary to inspect the full length of these structures.

Typical examples of culverts, tunnels and soil-steel structures are illustrated in Figure 8.1.5(c).

8.1.6 DIAPHRAGMS

Diaphragms are made of steel, wood or concrete components.

Diaphragms span between the primary load carrying components such as beams, girders, deck trusses or are located inside box sections. They are normally located in the vertical plane.

Diaphragms may be solid, or built up from individual steel or wood sections which are assembled together to form x-frames or k-frames using rivets, bolts, nails or by welding.

Diaphragms can be distinguished as load bearing or non-load bearing. Load bearing diaphragms directly support superstructure reactions or are designed for jacking purposes. Non-load bearing diaphragms provide lateral support or restraint to other superstructure components.

Typical diaphragms are illustrated in Figure 8.1.6.

8.1.7 SWAY BRACINGS

Sway bracings are made of concrete, steel or wood.

Sway bracings are the transverse bracings between primary components and are normally located in the vertical plane. In the case of half-through trusses the sway bracings are attached to the outside of each truss instead of between the trusses.

Sway bracings may be solid, or built up from individual steel or wood sections which are assembled together to form x-frames or k-frames using rivets, bolts, nails or by welding.

Typical sway bracings are illustrated in Figures 8.1.3(a) and Figure 8.1.4.

8.1.8 LATERAL BRACINGS

Lateral Bracings are made of steel or wood.

Lateral bracings are the transverse bracings between primary components such as beams, girders, trusses and arches and are normally located in the horizontal plane.

Lateral bracings are normally made from single components but sometimes may be made into frames.

Typical lateral bracings are illustrated in Figures 8.1.3(a), 8.1.3(c) and Figure 8.1.8.

8.2 PRIMARY COMPONENTS

The following are to be considered as primary components:

- beams, girders;
- thick slabs;
- truss top and bottom chords, verticals and diagonals;
- arch ribs, ties, vertical and diagonals;
- stringers and floor beams;
- load bearing diaphragms that directly support or transmit wheel loads.
- connections to primary components.
- barrel of culverts, tunnels and soil-steel structures.

8.2.1 MATERIAL DEFECTS OF PRIMARY COMPONENTS

Material defects are as given in Section 2.

8.2.2 PERFORMANCE DEFECTS OF PRIMARY COMPONENTS

Performance defects in primary components are related to their ability to support the dead and live loads imposed on them and to transmit those loads to the substructure without excessive deformations or vibrations.

8.3 SECONDARY COMPONENTS

The following are to be considered as secondary components:

- Non-load bearing diaphragms that do not directly support or transmit wheel loads;
- Sway bracings;
- Lateral bracings;
- Connections to secondary components.
- Inlet and outlet treatments of culverts.

8.3.1 MATERIAL DEFECTS OF SECONDARY COMPONENTS

Material defects are as given in Section 2.

8.3.2 PERFORMANCE DEFECTS OF SECONDARY COMPONENTS

The performance condition rating of non-load bearing diaphragms is based upon their ability to restrict relative vertical and transverse movements between the primary components and thus transmit vertical and transverse loads between them without excessive or permanent deformations.

The performance condition rating of sway bracings is based upon their ability to restrict relative transverse and vertical movements between primary components and thus prevent lateral buckling of primary components.

The performance condition rating of lateral bracings is based upon their ability to restrict relative longitudinal and transverse movements between primary components and thus transmit longitudinal and transverse loads between them without excessive or permanent deformations.

The performance condition rating of inlet and outlet treatments of culverts is based upon their ability to provide for the functions they are designed for.

8.4 REFERENCES

1. The Bailey and Uniflote Handbook, 1974, Acrow Corporation of America

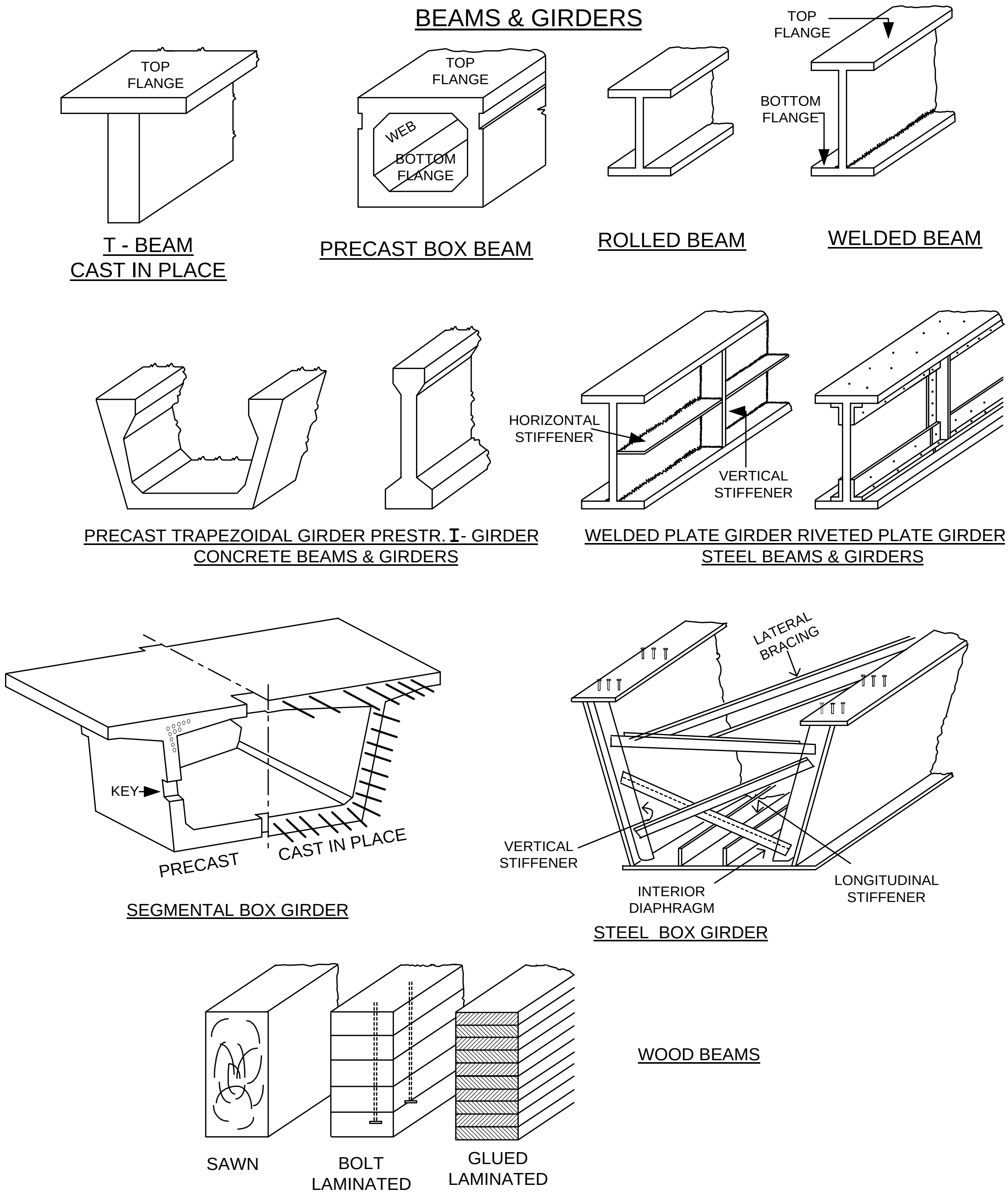
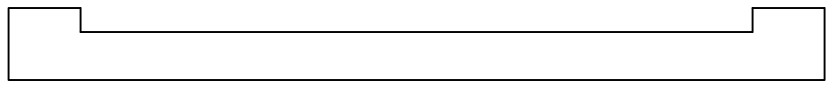
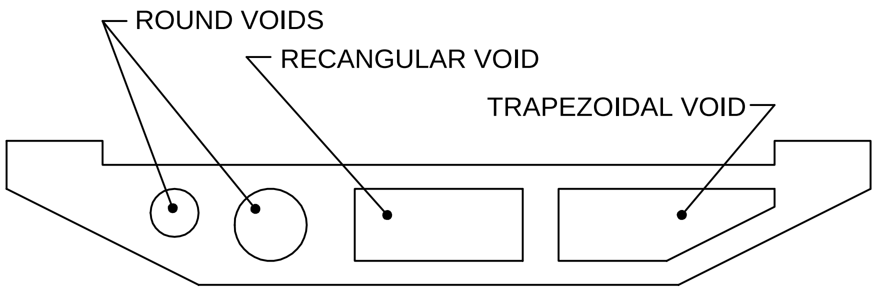


Figure 8.1.1 Beams and Girders



Solid Thick Slab



Voided Thick Slab

Figure 8.1.2 Thick Slabs

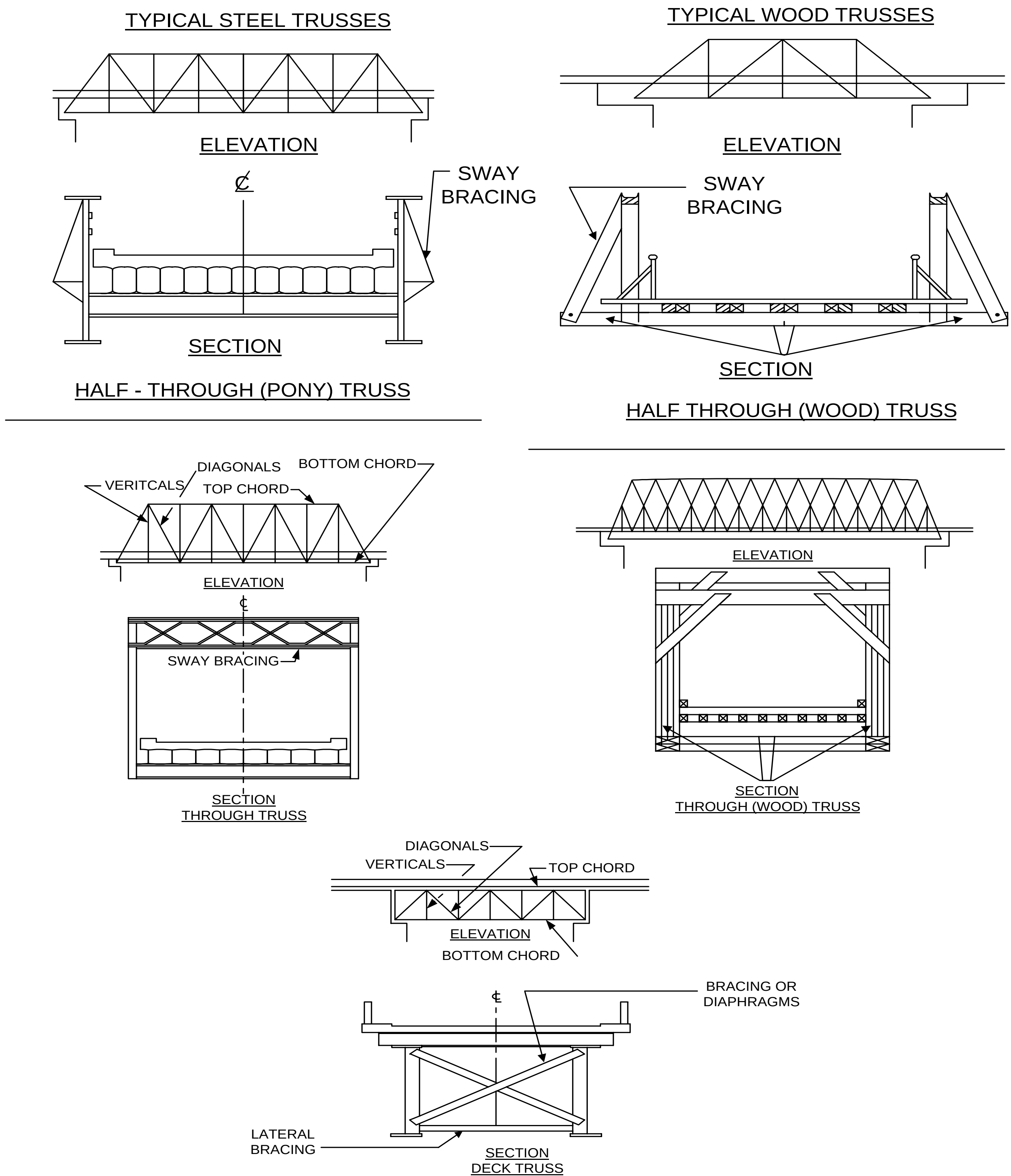
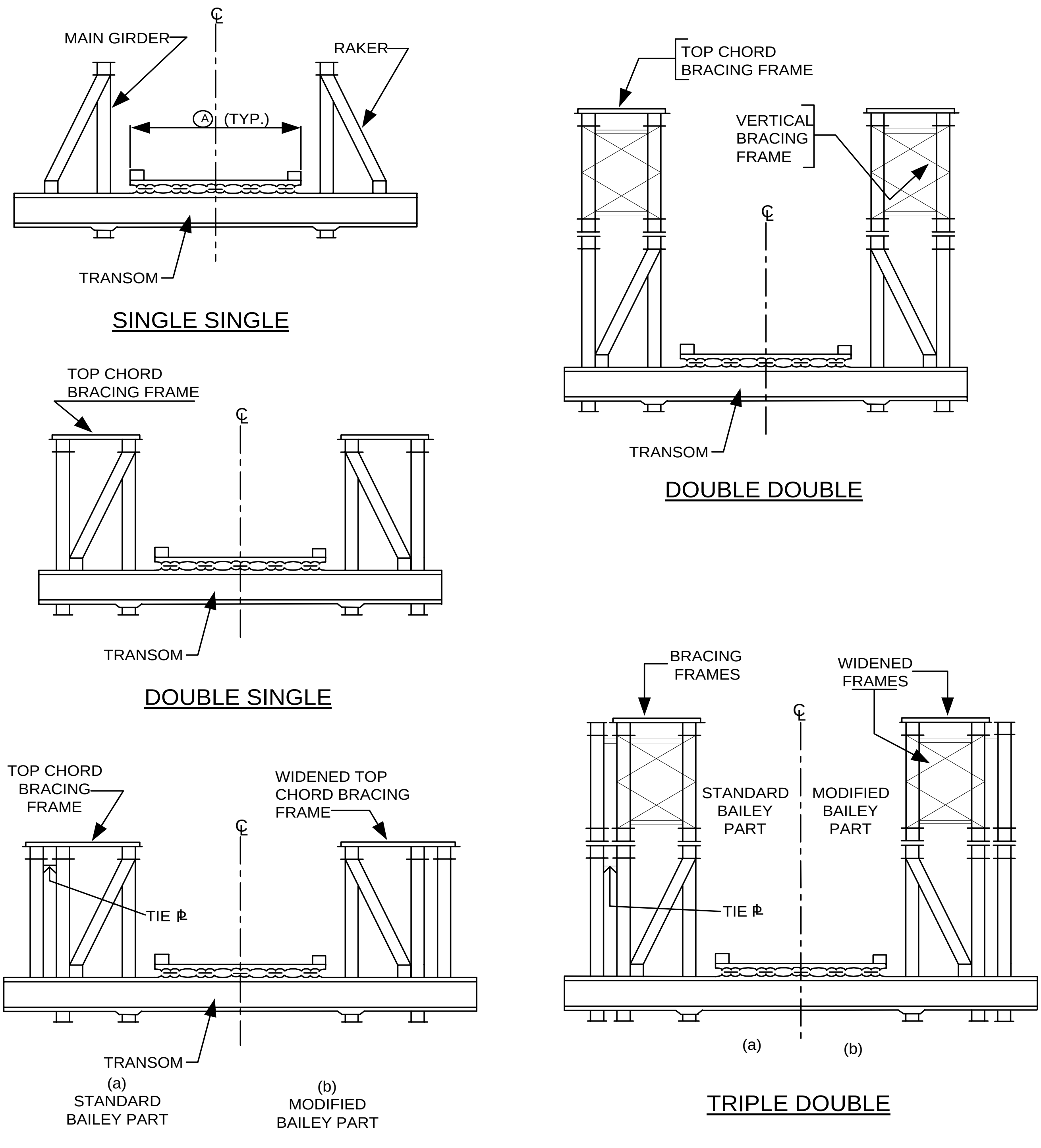


Figure 8.1.3(a) Trusses



TRIPLE SINGLE

DIMENSION (A)
STANDARD BAILEY..................... 3759 mm
STANDARD WIDENED BAILEY... 4343 mm

Figure 8.1.3(b) Typical Bailey Configurations

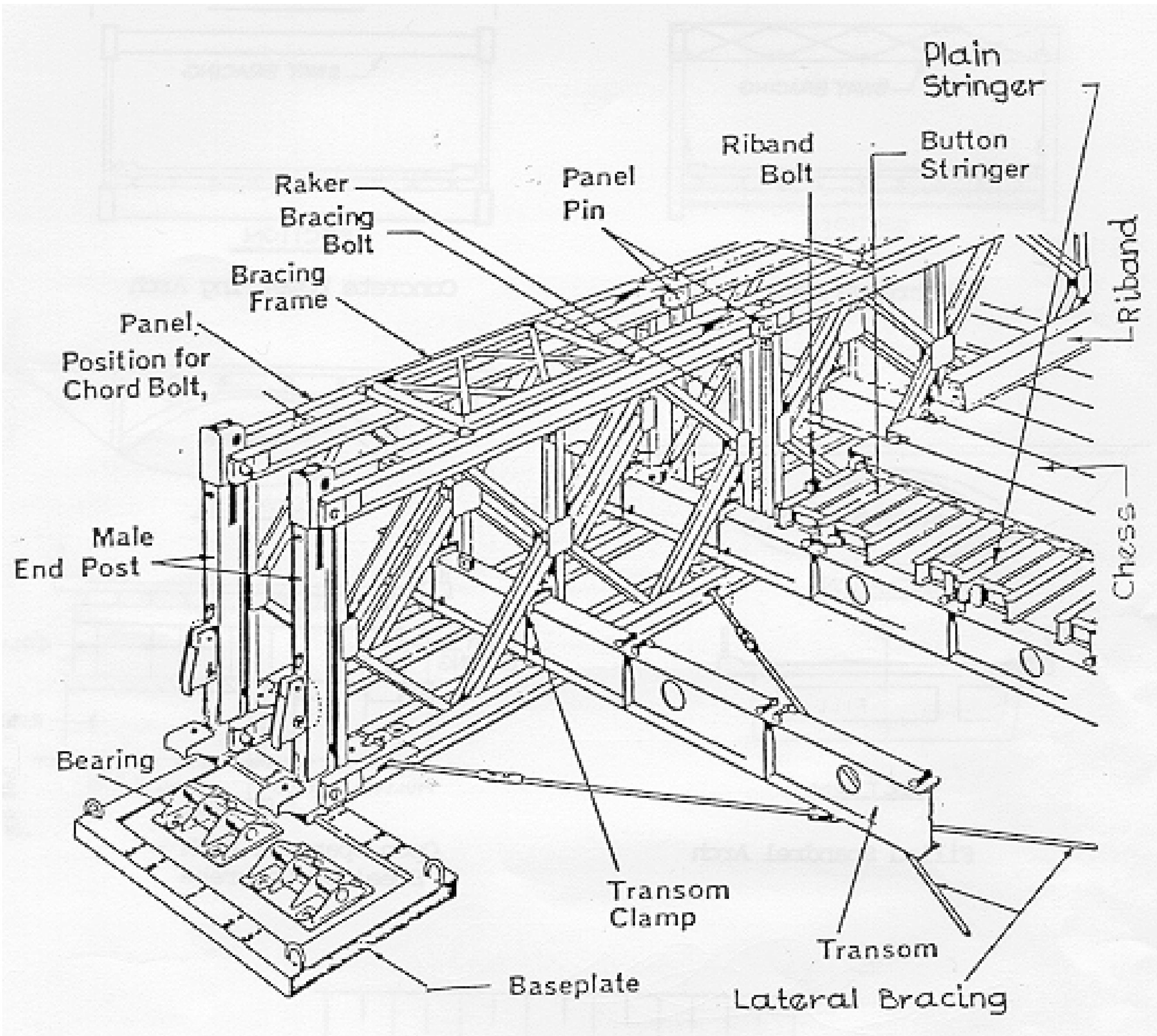


Figure 8.1.3(c) Typical Bailey Components

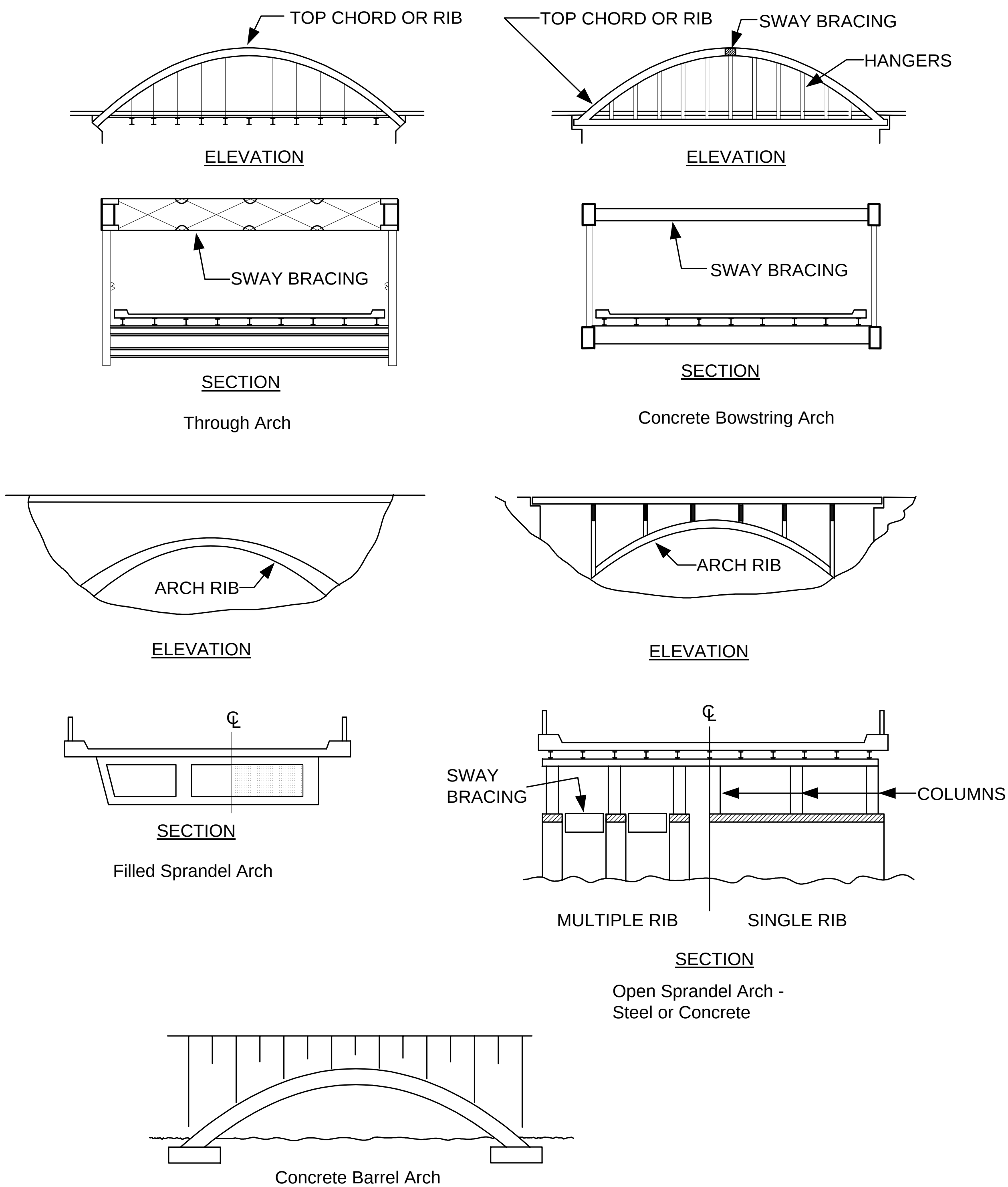


Figure 8.1.4 Arches

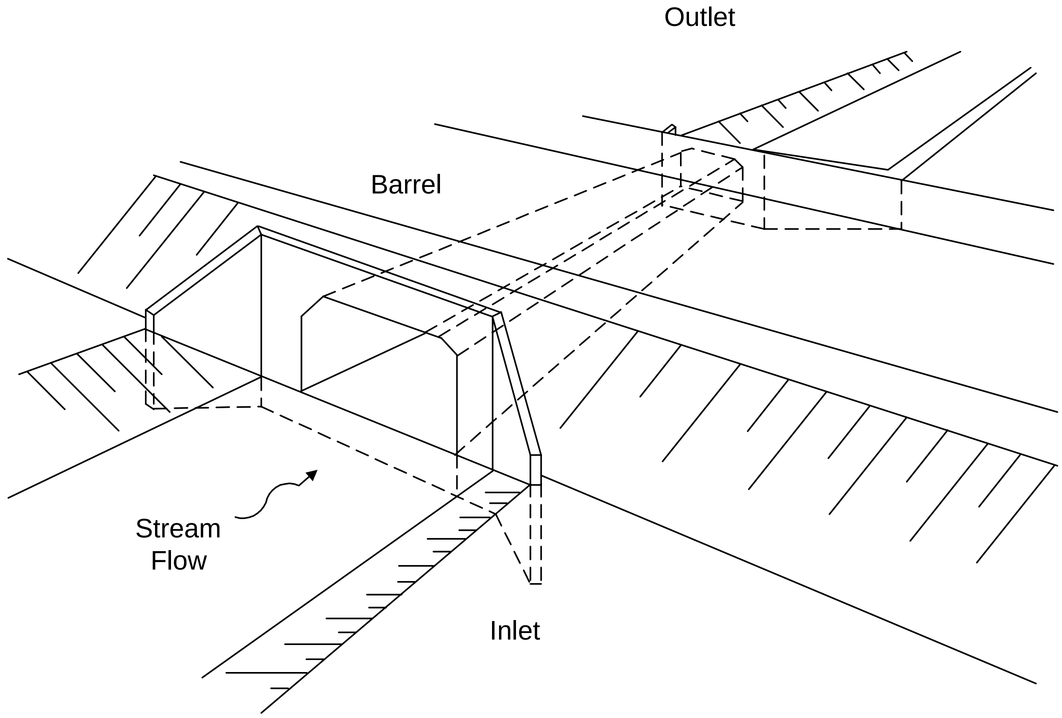


Figure 8.1.5(a) Basic Culvert, Tunnel and Soil-Steel Structure Components

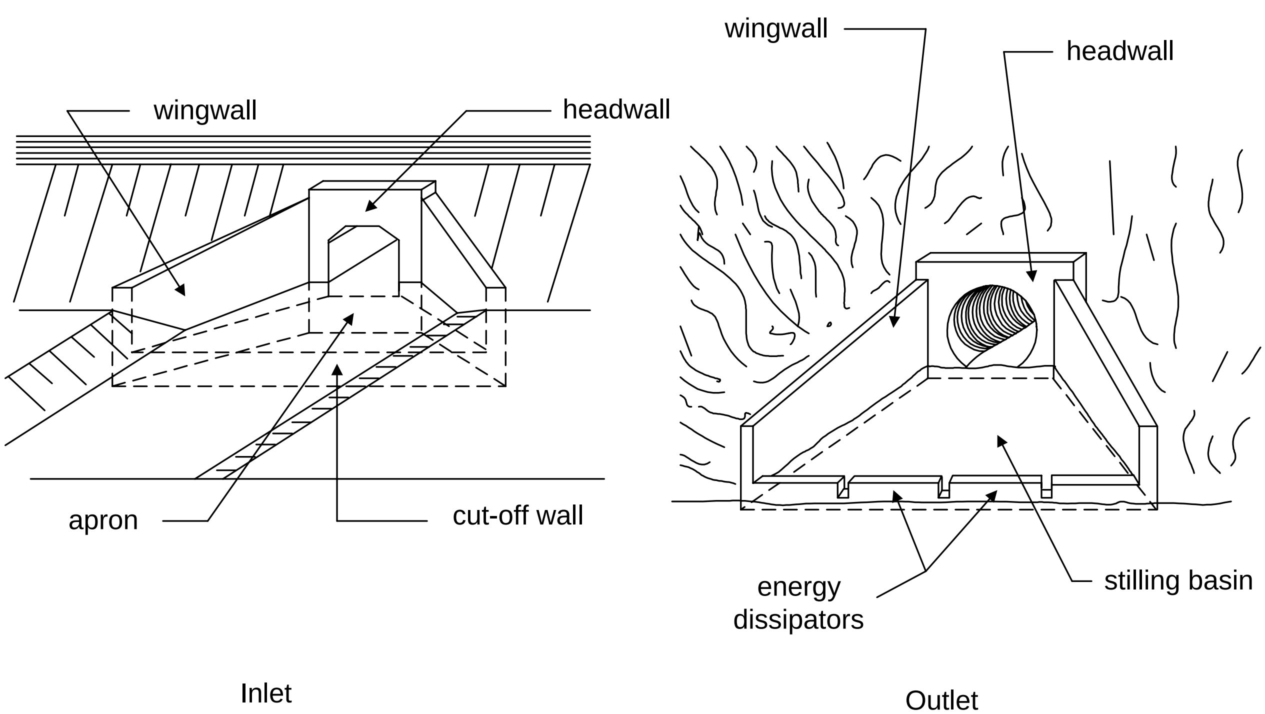
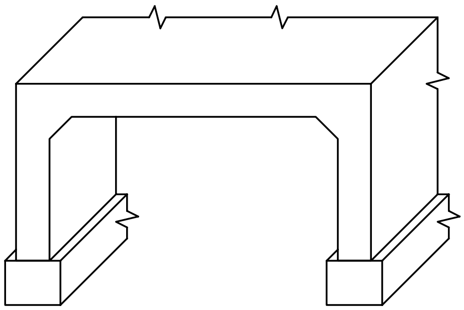
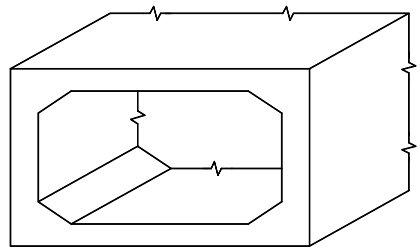


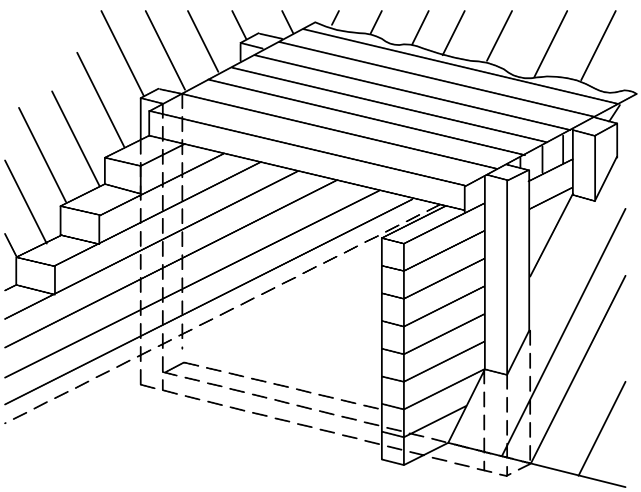
Figure 8.1.5(b) Typical Inlet and Outlet Components



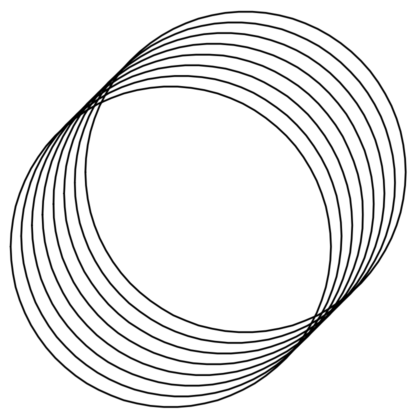
Open Footing Concrete Culvert



Concrete Box Culvert



Wood Culvert



Round Corrugated Pipe Culvert

Figure 8.1.5(c) Typical Culverts and Tunnels

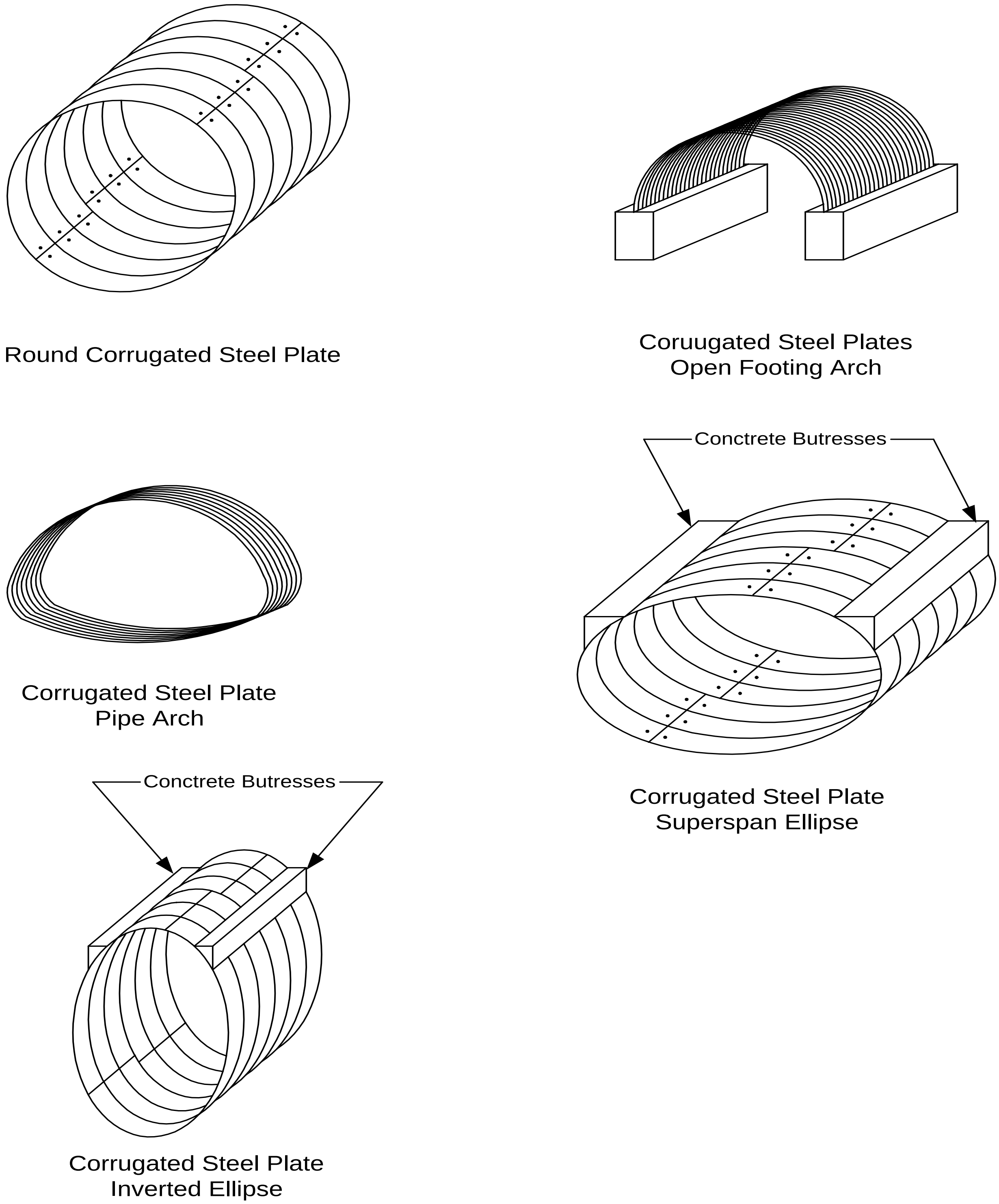


Figure 8.1.5(d) Typical Soil-Steel Structures

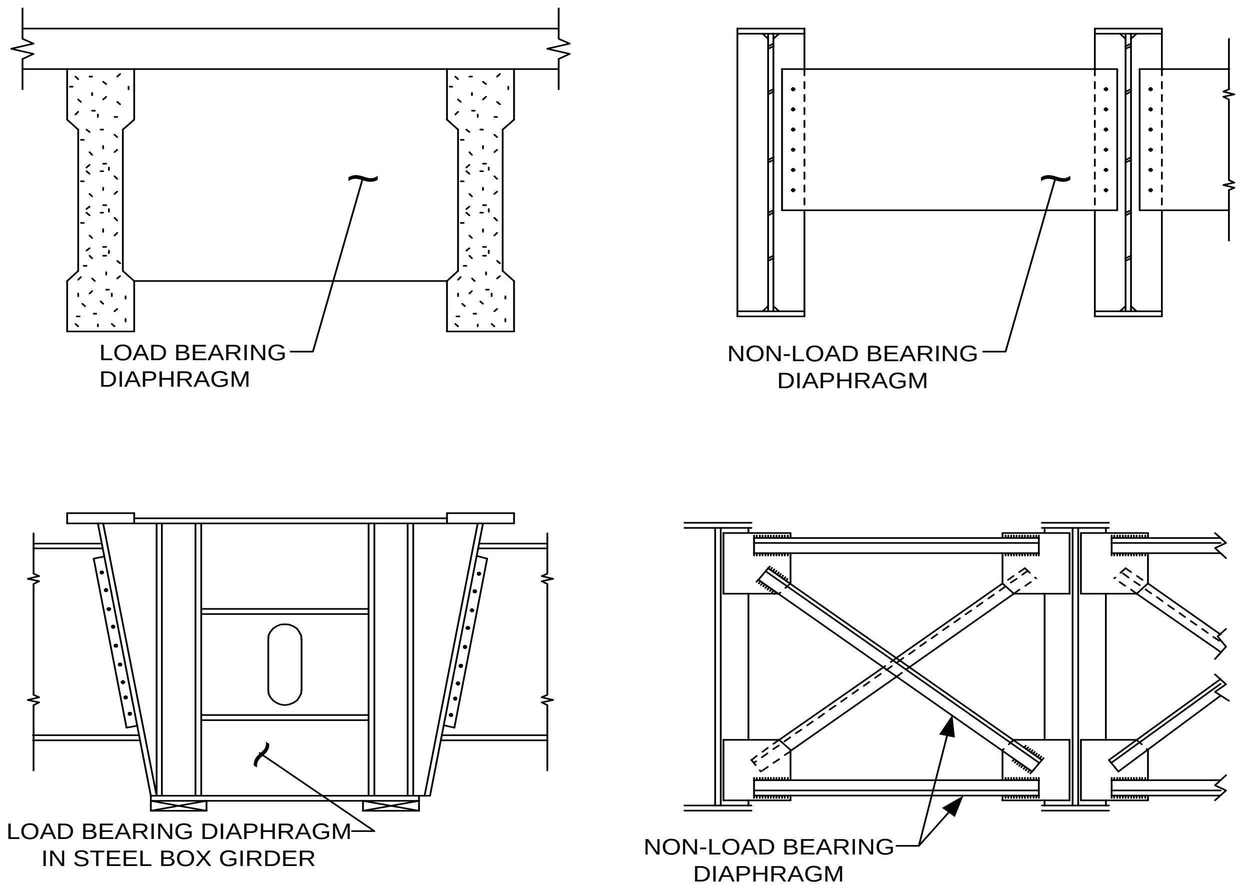


Figure 8.1.6 Diaphragms

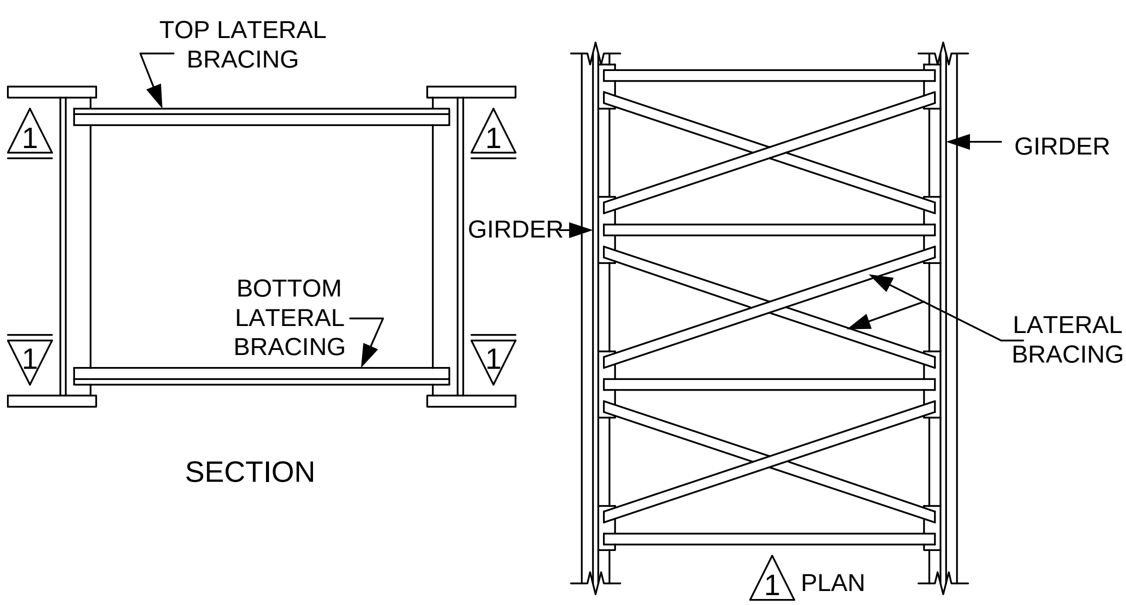


Figure 8.1.8 Lateral Bracing

SECTION 9 - DECK COMPONENTS

Contents

9.1 DECK COMPONENTS

The following components are considered in this section:

- Decks
- Wearing Surfaces
- Curbs and Sidewalks
- Approaches and Approach Slabs and Ramps
- Drainage and Deck Drains

9.1.1 DECKS

The types of decks commonly used are:

- Reinforced Concrete Decks;
- Wood Decks;
- Orthotropic Steel Decks;
- Open Grating Steel Decks; and
- Corrugated Metal Sheeting Decks.

Reinforced concrete decks are the most common type of deck used in structures. They are commonly cast-in-place but may also be pre-cast. This type of deck includes slab on beams, and the top surface of solid or voided thick slabs, or of rigid frames.

Wood decks are commonly used on secondary roads and rural highways. Types of wood decks commonly used include longitudinal and transverse laminated wood decks, prestressed wood decks, plank decks and composite wood and concrete decks.

Orthotropic steel decks consist of a flat steel top plate surface welded to a supporting system of steel girders, floor beams and ribs. Flat bars or studs are often welded to the top steel plate to improve the bond with the wearing surface.

Prefabricated steel grating is sometimes used as decking material. The open mesh grating panels are installed over a network of steel floor beams and stringers to form the riding surface. A variation of this deck is produced by placing a concrete infill slab over the grating to form a composite deck surface.

Corrugated metal sheeting decks have been used in a few cases. They are normally overlaid with asphalt or concrete wearing surface.

Figure 9.1.1 illustrates the types of decks commonly encountered.

9.1.2 WEARING SURFACES

The top surface of the deck is either left exposed and acts as the wearing surface or is protected by an additional wearing surface. A waterproofing membrane placed between the deck and asphalt wearing surface also provides additional protection.

Reinforced concrete and steel decks are typically covered with an asphalt wearing surface, with or without waterproofing. Wood decks are typically covered with an asphalt, concrete or wood planking wearing surface, normally without waterproofing.

Wearing surfaces are shown in Figure 9.1.1.

9.1.3 CURBS AND SIDEWALKS

Curbs are located parallel to the side limits of the roadway and are constructed between 150 mm and 600 mm in width and extend between 150 mm and 250 mm in height above the roadway surface.

Sidewalks are located along the edge of the deck and elevated above the level of the deck. They are sometimes built on supports which cantilever beyond the deck limits. These supports shall be inspected as part of the sidewalks. The width of sidewalks usually ranges from 1500 mm to 2000 mm in high pedestrian volume urban areas; and from 300 mm to 600 mm in low pedestrian volume rural areas.

Curbs and sidewalks can be constructed of concrete, wood, asphaltic concrete or steel. Precast masonry is sometimes used as well.

Typical examples of curb and sidewalk construction are illustrated in Figures 9.1.1 and 9.1.3.

9.1.4 APPROACHES, APPROACH SLABS AND RAMPS

Approaches for a length of 30 m beyond each end of the structure shall be inspected.

Approach slabs are located at each end of the structure, however, they may not be present at some structures on lightly travelled roads or on gravel roads.

Approach slabs, where present, are constructed upon the approach embankment. One end of the approach slab is anchored to the ballast wall or abutment wall, the other end rests upon the approach fill and is free to move.

Where approach slabs are present, they are often paved over with an asphalt wearing surface.

Approach ramps are sometimes provided at the approach to bailey bridges.

A typical concrete approach slab is illustrated in Figure 9.1.4.

9.1.5 DRAINAGE AND DECK DRAINS

Surface drainage on structures is channelled along the curbs and drained through deck drains or allowed to drain off the deck. Drainage from the approaches is normally drained into drainage ditches or caught at catch basins before it reaches the structure.

Deck drains are usually located along the curb lines. Deck drains are typically made of steel, although concrete, aluminum, acrylonitrile butadiene styrene (ABS) and polyvinylchloride (PVC) are sometimes used as well. Steel drains are usually galvanized or made of atmospheric corrosion resistant steel. Deck drains are anchored to the deck by metal bars, or rely on their shape and bonding forces to secure them in place.

Deck drains vary in size and shape, and vary from single pipes to prefabricated pipe and catch basin units. Deck drains can also occur individually or be interconnected to an extensive collection system terminating at storm sewers. In either case, deck drains must extend below or away from structure components below the deck to prevent water discharge or spray from falling on those components.

Deck drains, in concrete decks, normally have drainage holes in them, at the interface between the deck top surface and the asphalt wearing surface, to drain water that has penetrated through the wearing surface.

Concrete decks with dams at expansion joints usually have 25mm diameter PVC tubes placed through the deck, from the interface of the wearing surface and deck top surface, to drain water which penetrates through the wearing surface.

Precast concrete box girders and steel box girders have drain holes in the bottom flange to drain off any water that finds its way into the boxes. These also serve to provide ventilation.

Drainage ditches, gutters and catch basins in the approaches to the structure are detailed in References 1 and 2.

Figure 9.1.5 illustrates typical examples of drainage systems and deck drains commonly encountered.

9.2 PRIMARY COMPONENTS

Decks and wearing surfaces shall be considered as primary components.

9.2.1 MATERIAL DEFECTS OF PRIMARY COMPONENTS

Material defects are as given in Section 2.

The top surfaces of exposed decks are directly subject to the adverse effects of weather, traffic and the use of de-icing salts and chemicals. This results in rapid deterioration of the decks.

Even with the added protection of the wearing surfaces, the deck top surfaces below the wearing surfaces of covered decks are often prone to similar deteriorations as exposed decks. Unfortunately, the wearing surfaces may hide these defects on the deck surfaces until they are well advanced.

9.2.2 PERFORMANCE DEFECTS OF PRIMARY COMPONENTS

Performance of decks relate to their ability to support imposed live and dead loads, to transit those loads to the supporting superstructure components and to provide safe and smooth riding surfaces for traffic.

Performance of wearing surfaces relate to their ability to provide safe and smooth riding surfaces and to protect the underlying decks from deterioration.

9.3 SECONDARY COMPONENTS

Curbs, sidewalks, approaches, approach slabs and ramps are to be considered as secondary components.

9.3.1 MATERIAL DEFECTS OF SECONDARY COMPONENTS

Material defects are as given in Section 2.

9.3.2 PERFORMANCE DEFECTS OF SECONDARY COMPONENTS

Performance of curbs and sidewalks relates to their ability to provide safe and comfortable passage for pedestrians, and to protect structure components beyond the roadway limits from vehicular collision and damage. Curbs also serve to channel roadway surface drainage to deck drainage systems.

Performance of approaches, approach slabs and ramps relates to their ability to provide smooth transition for traffic onto and off the structure. Performance of approach slabs also relates to their ability to distribute live loads through the embankment and to the abutment wall.

9.4 AUXILIARY COMPONENTS

Deck drains, drainage ditches, gutters and catch basins shall be considered as auxiliary components.

9.4.1 MATERIAL DEFECTS OF AUXILIARY COMPONENTS

Material defects are as given in Section 2.

9.4.2 PERFORMANCE DEFECTS OF AUXILIARY COMPONENTS

The performance of deck drains and drainage systems relates to their ability to remove water from the deck and approaches, and to direct and discharge it safely away from the structure and its components.

Trapped or ponded water is a safety hazard, particularly when frozen, as it can lead to loss of vehicle control. It can also result in deterioration of the deck and other components.

Inadequate discharge of approach drainage results in erosion of the approach fills and loss of support for structure components.

Deck drains and drainage systems discharging onto structure components result in rapid deterioration of those components.

9.5 REFERENCES

1. MTC Drainage Manual.

2. Highway Engineering Standards - Roads, Barriers and Drainage.

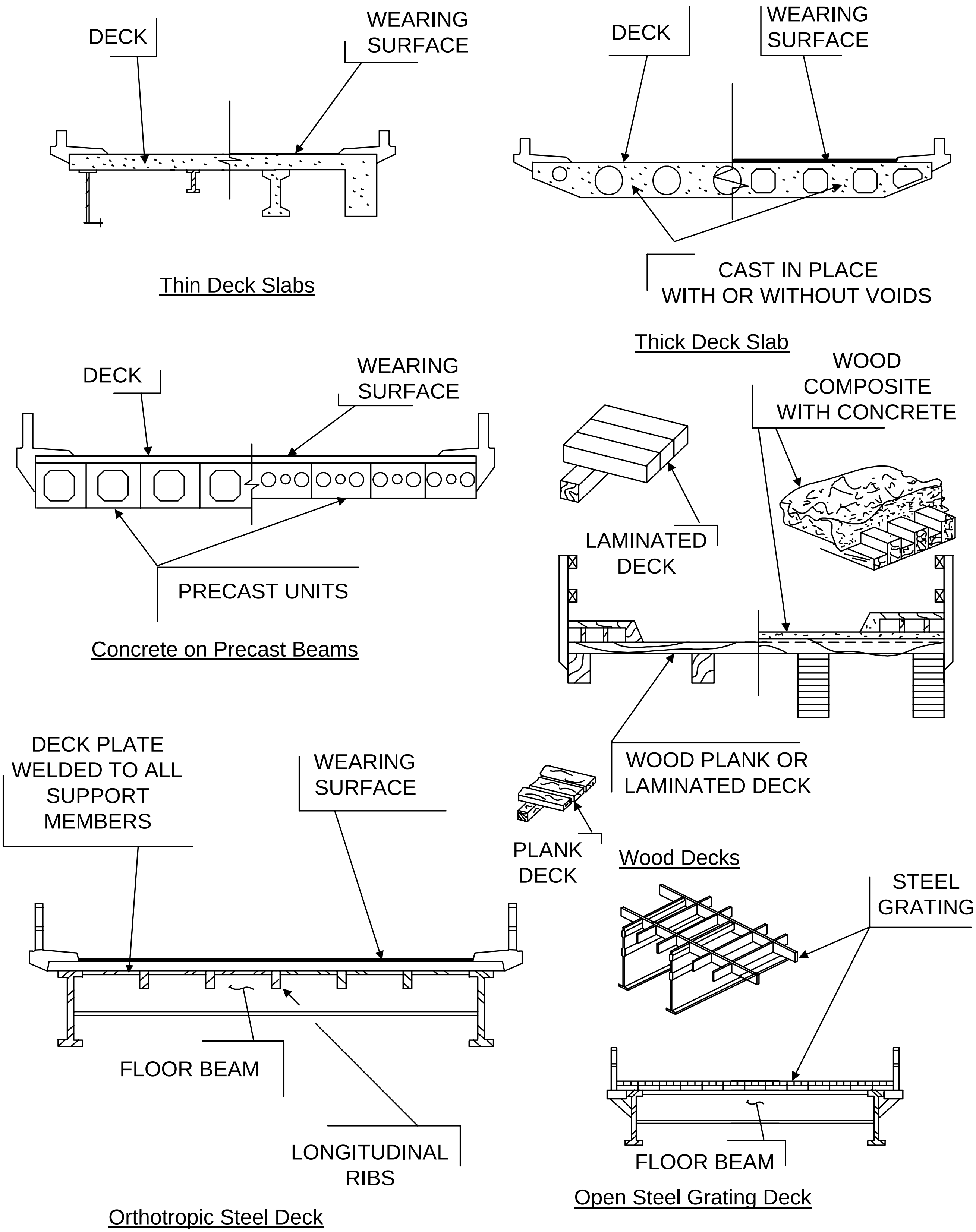
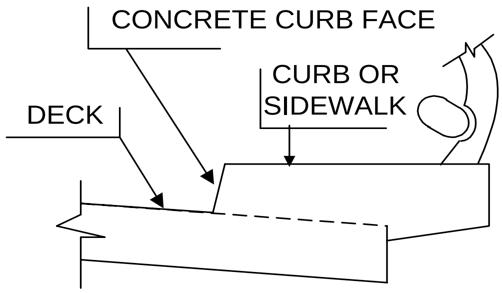
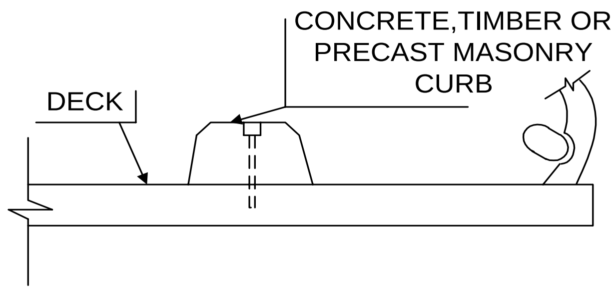


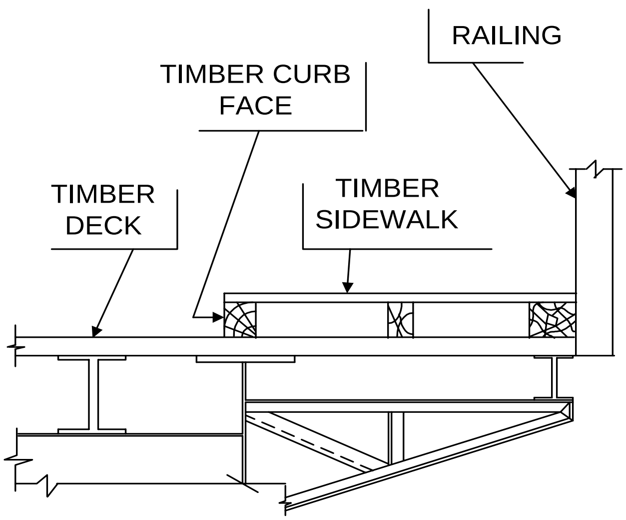
Figure 9.1.1 Typical Decks



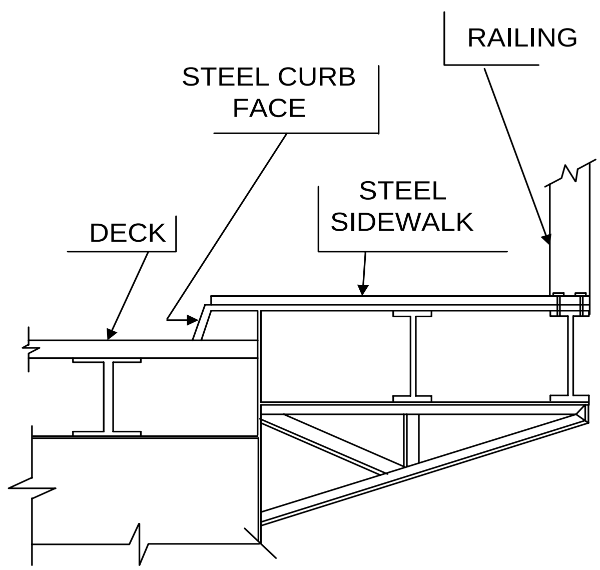
Concrete Curb or Sidewalk



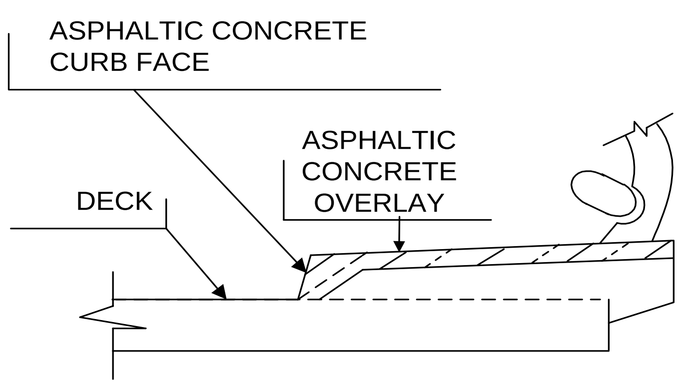
Curb With Sidewalk



Timber Cantilever Sidewalk



Steel Cantilever Sidewalk



Asphaltic Concrete Sidewalk

Figure 9.1.3 Typical Curbs and Sidewalks

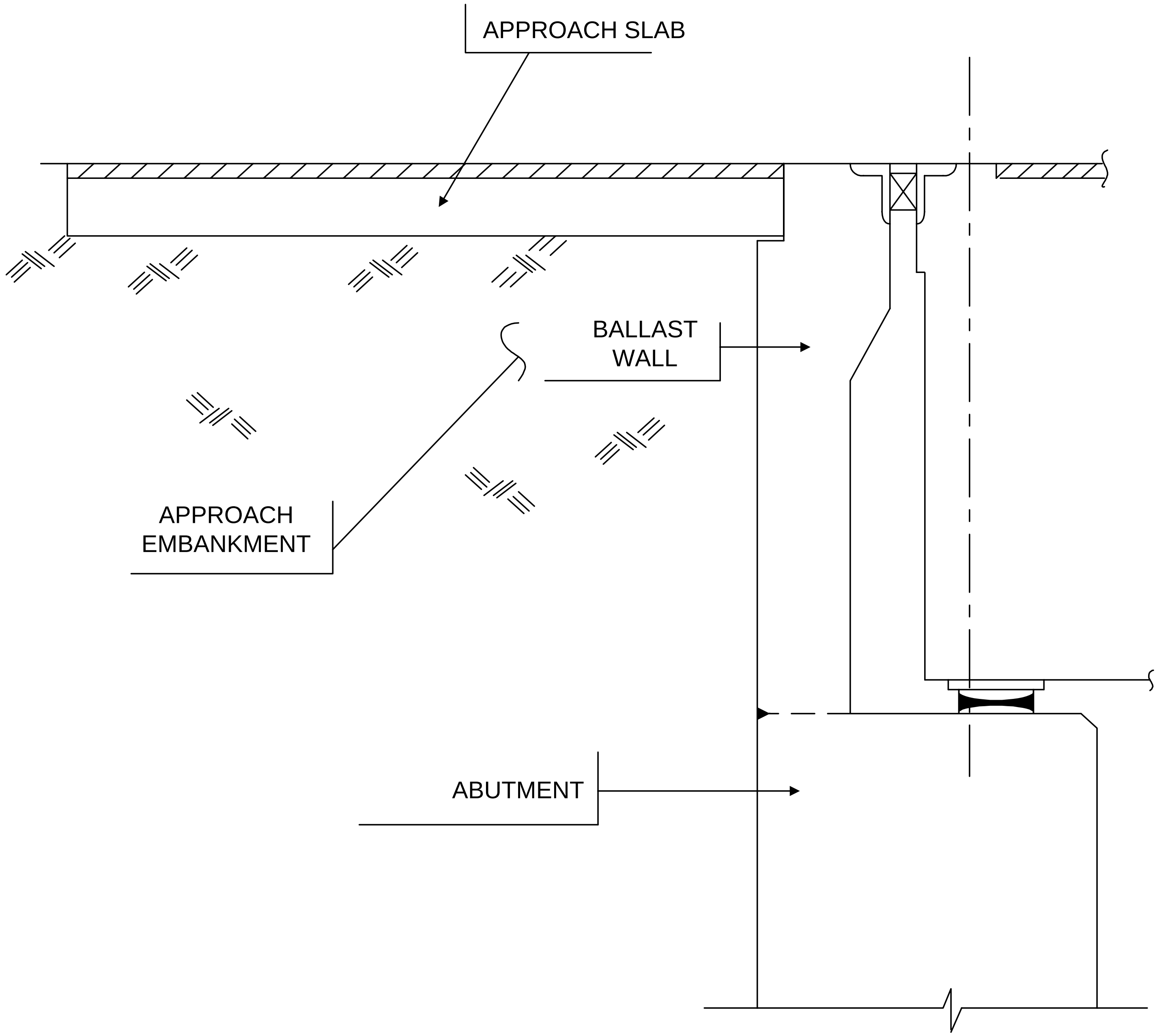


Figure 9.1.4 Concrete Approach Slab

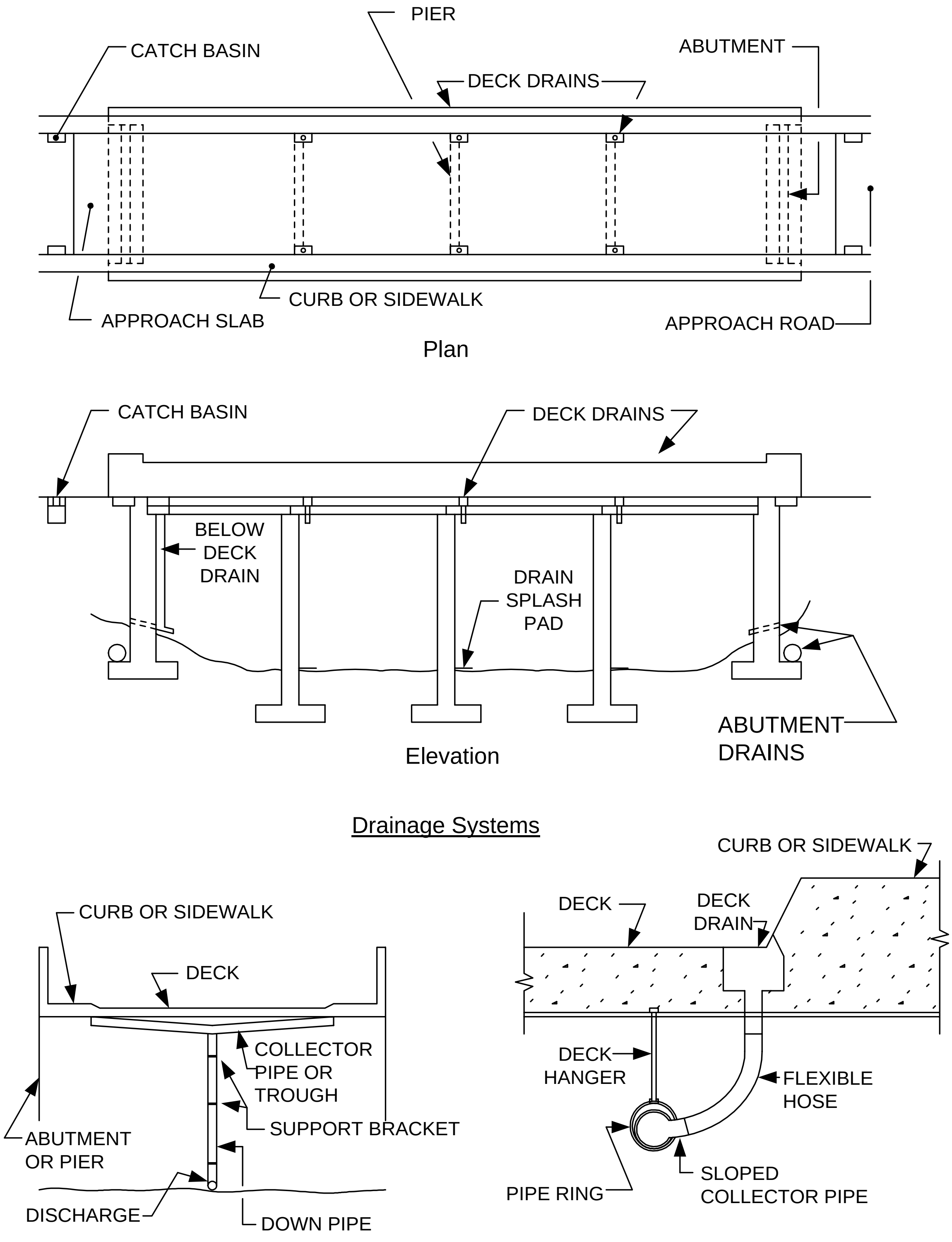
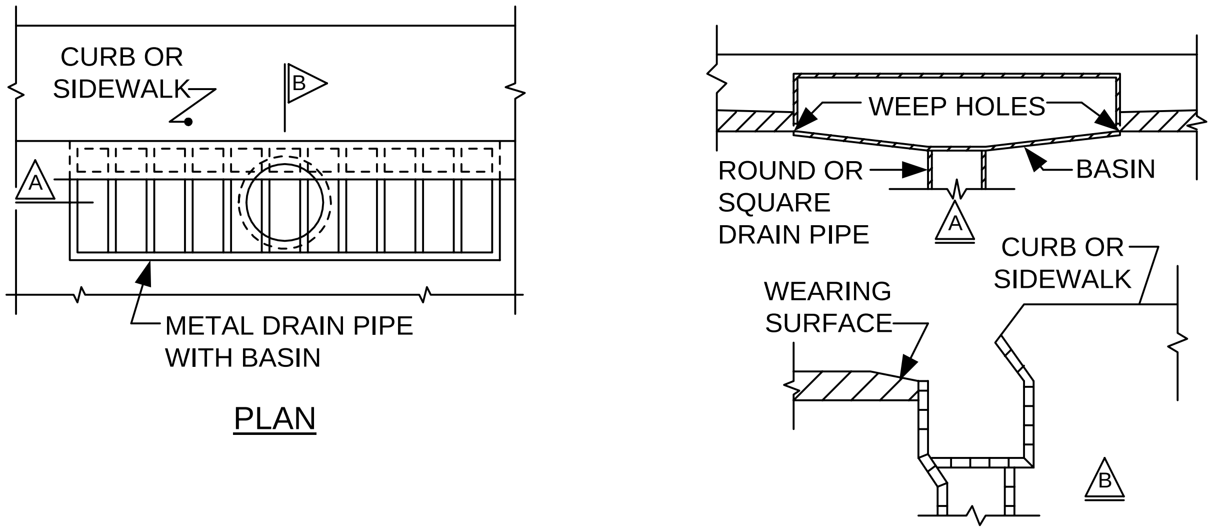
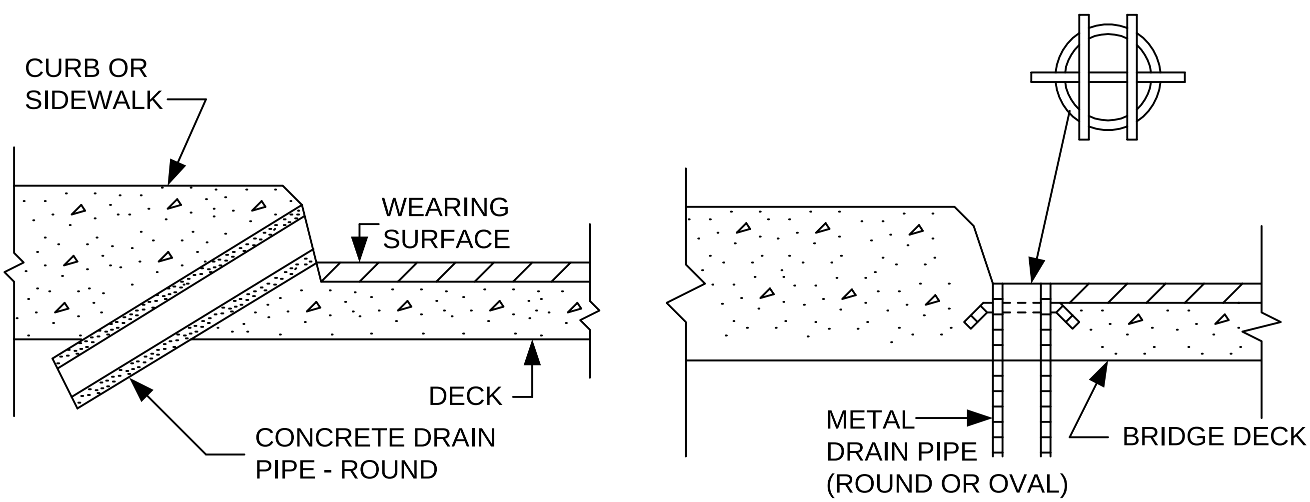


Figure 9.1.5 Drainage and Deck Drains



Drain Pipe With Basin



Drain Pipes Without Basins

Figure 9.1.5 Drainage and Deck Drains(cont'd)

SECTION 10 - RAILING SYSTEMS

Contents

10.1 RAILING SYSTEMS

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

Railing systems are located at the outermost side limits of the roadway or sidewalk, and may also be located along the median for separation of two way traffic.

Railing systems, post anchorages and rail connections are described below and illustrated in Figure 10.1.

(a) Parapet Walls

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

(b) Barrier Walls

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

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

(c) Railings

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

The following posts and railings are commonly encountered:

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

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

(d) Splash Guards

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

(e) Post Anchorages

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

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

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

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

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

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

(f) Rail Connections

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

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

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

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

10.1.1 MATERIAL DEFECTS OF RAILING SYSTEMS

Material defects are as given in Section 2. In addition, defects in railings using cables are:

- broken wires or entire cable;
- loose cables or inadequate cable tension;
- loose or corroded splices or fittings.

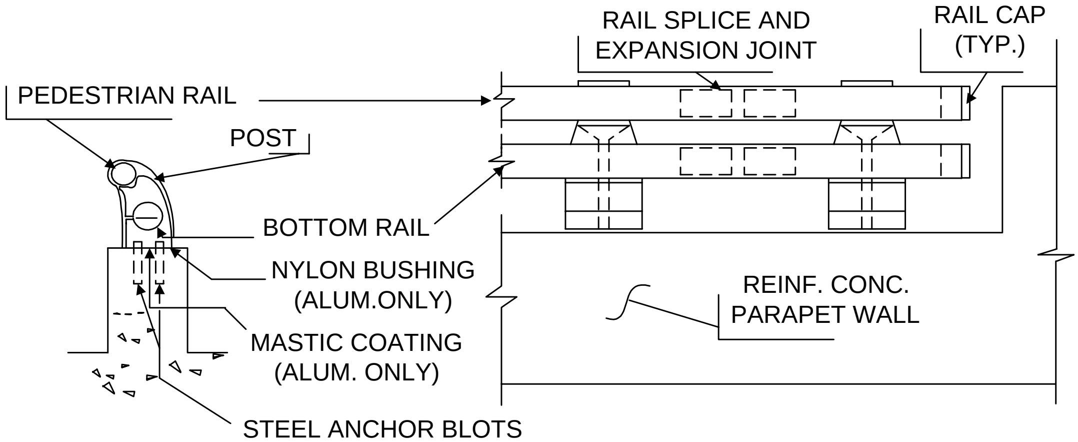
10.1.2 PERFORMANCE DEFECTS OF RAILING SYSTEM

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

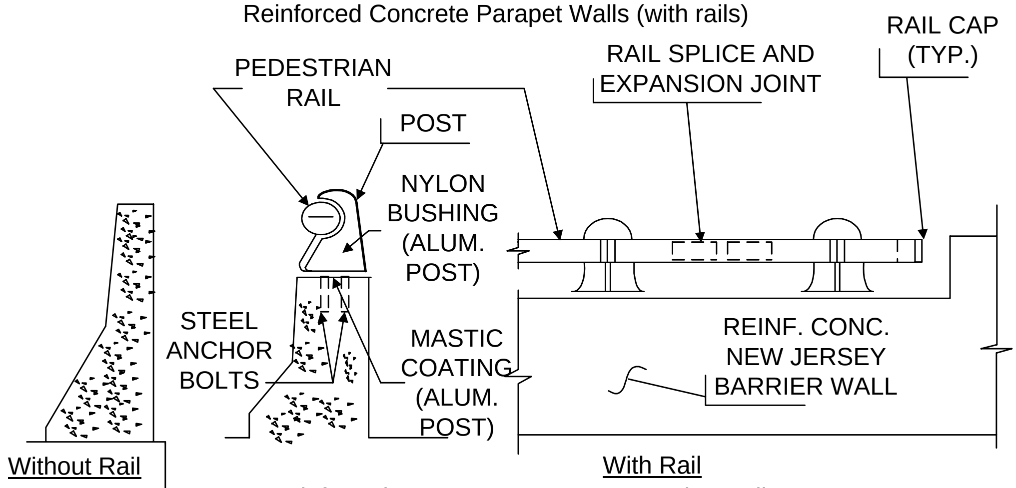
The performance of the top rail on parapet walls, barrier walls and railings is based on its ability to provide a handrail for pedestrians, to withstand or absorb some vehicular impact and to provide lateral support for some types of railings.

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

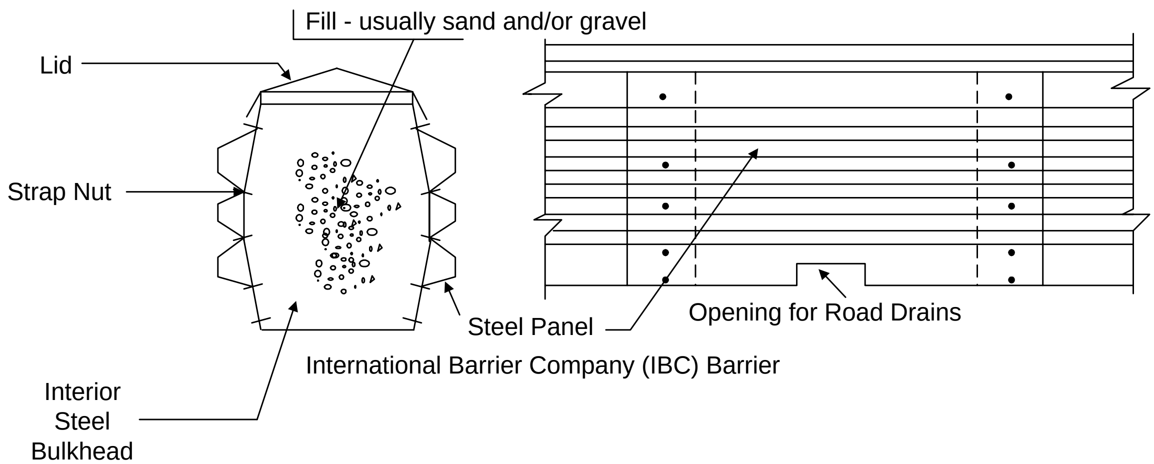
The performance of railing systems shall also be based upon their present condition with regards to their ability to meet the safety standards and other requirements in effect at the time they were originally installed.



Reinforced Concrete Parapet Walls (with rails)



Reinforced Concrete New Jersey Barrier Wall



International Barrier Company (IBC) Barrier

Figure 10.1 Railing Systems

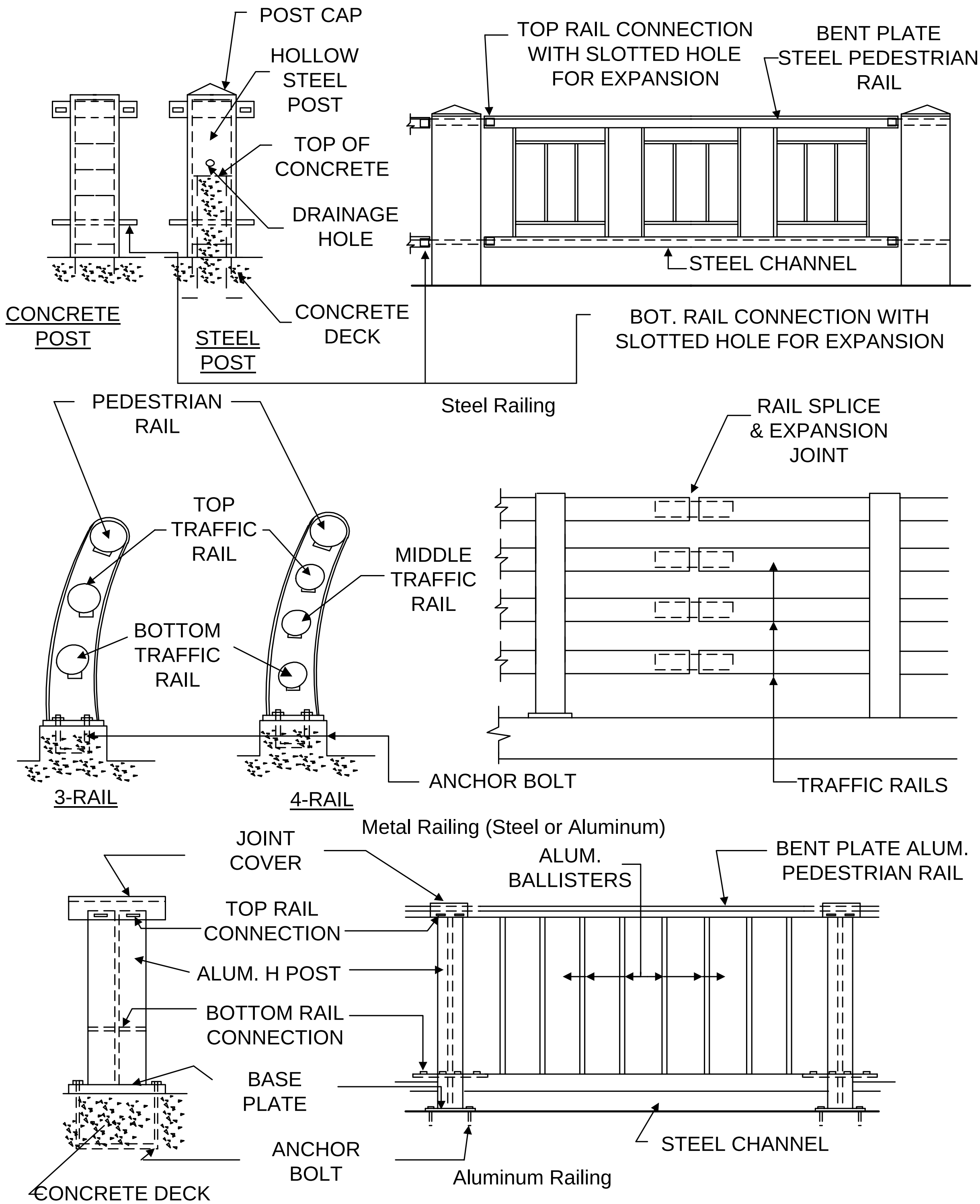
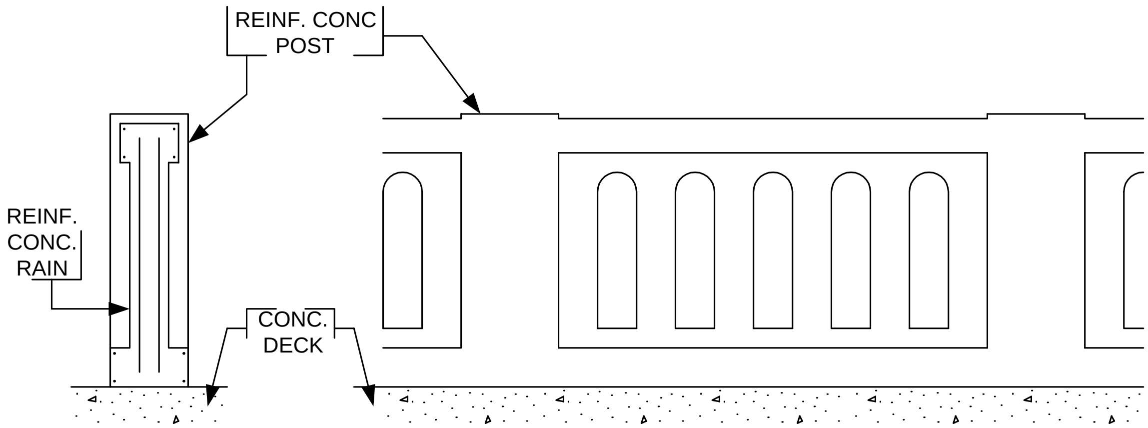
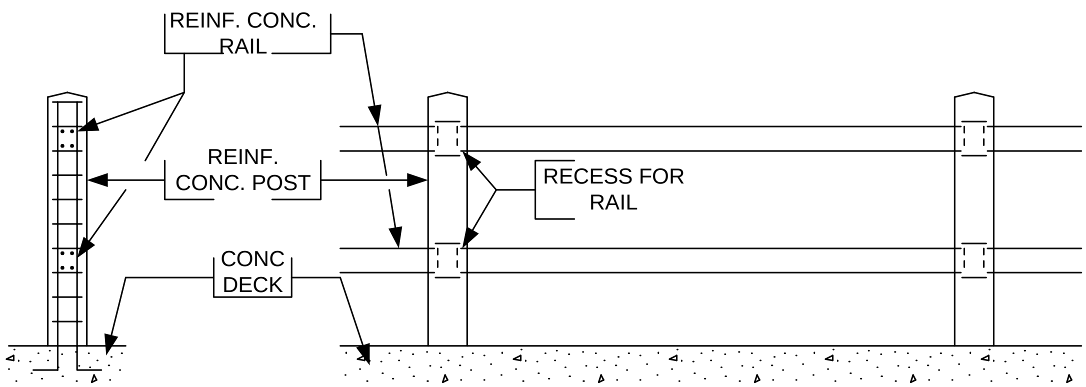


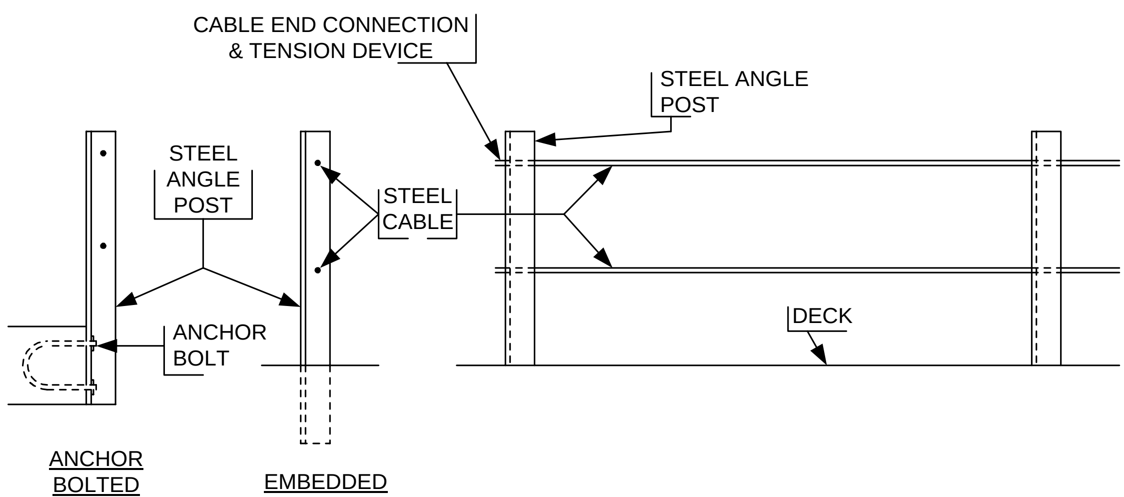
Figure 10.1 Railing Systems (cont'd)



Reinforced Concrete Railing

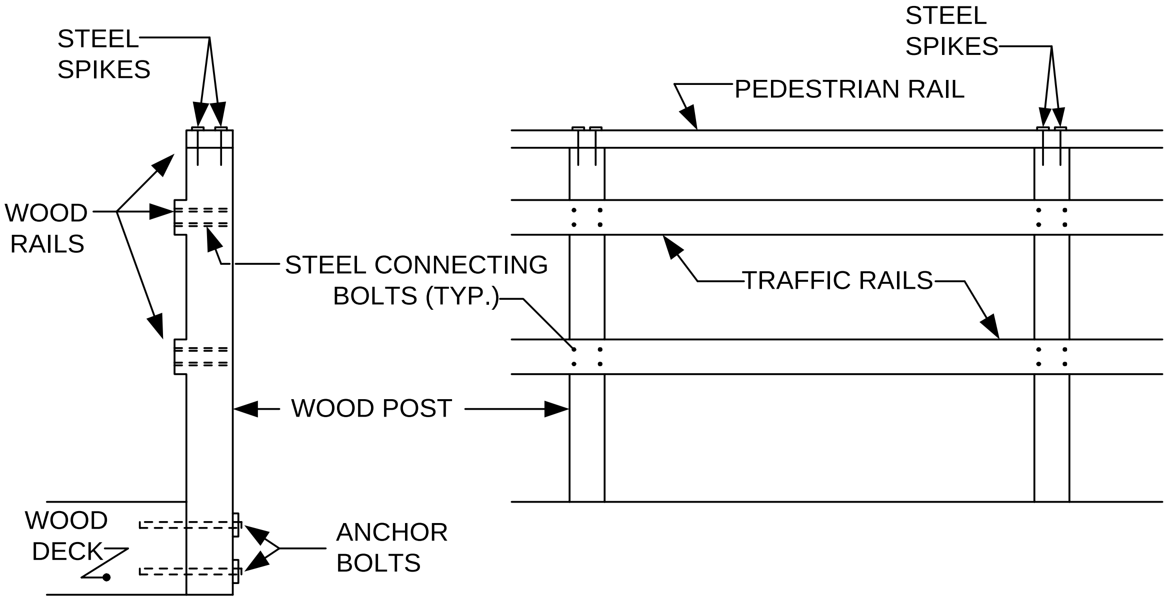


Reinforced Concrete Railing

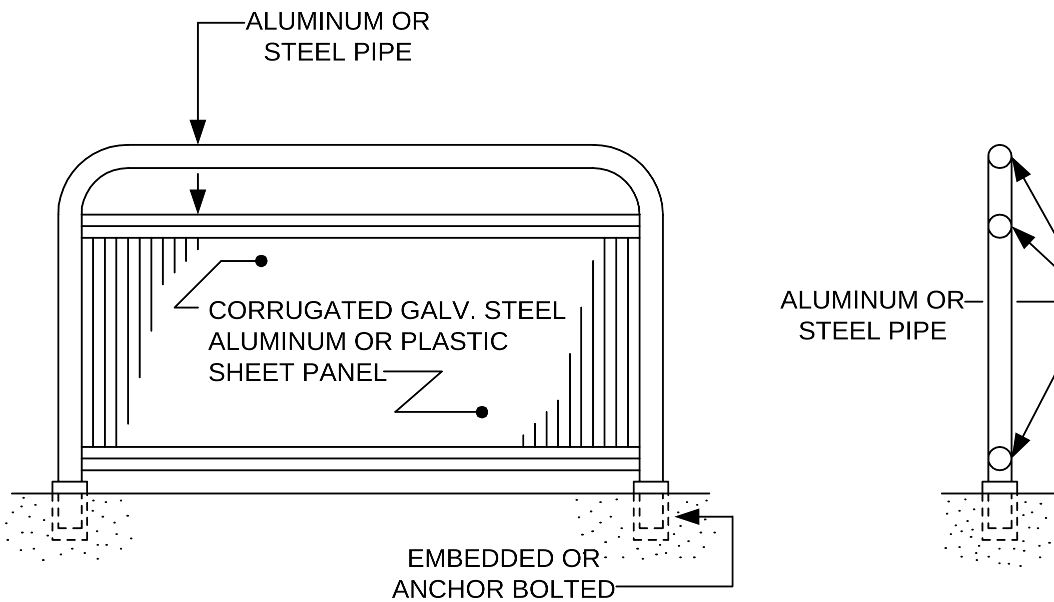


Steel Post and Cable Railing

Figure 10.1 Railing Systems (cont'd)

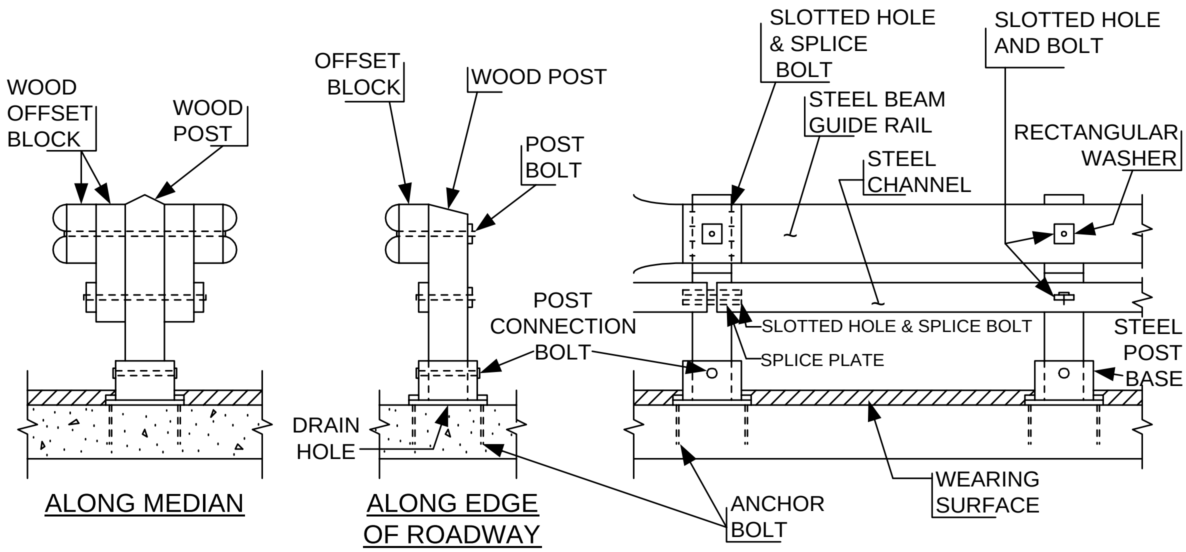


Wood Railing

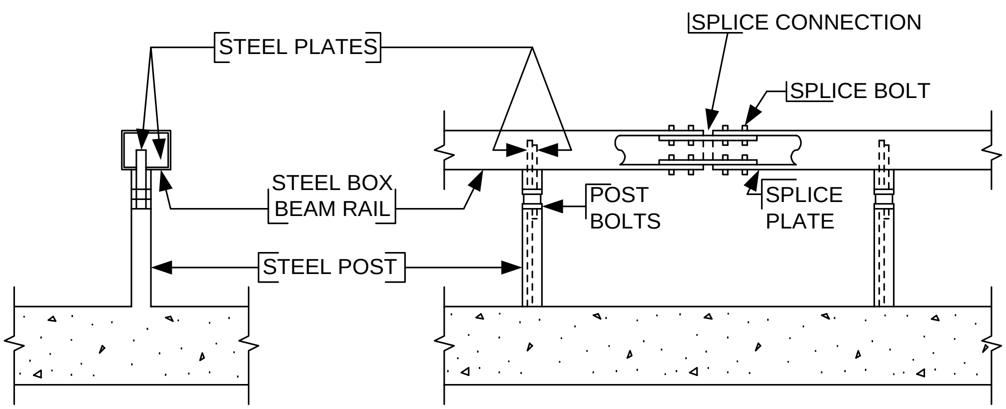


Railing With Splash Guard

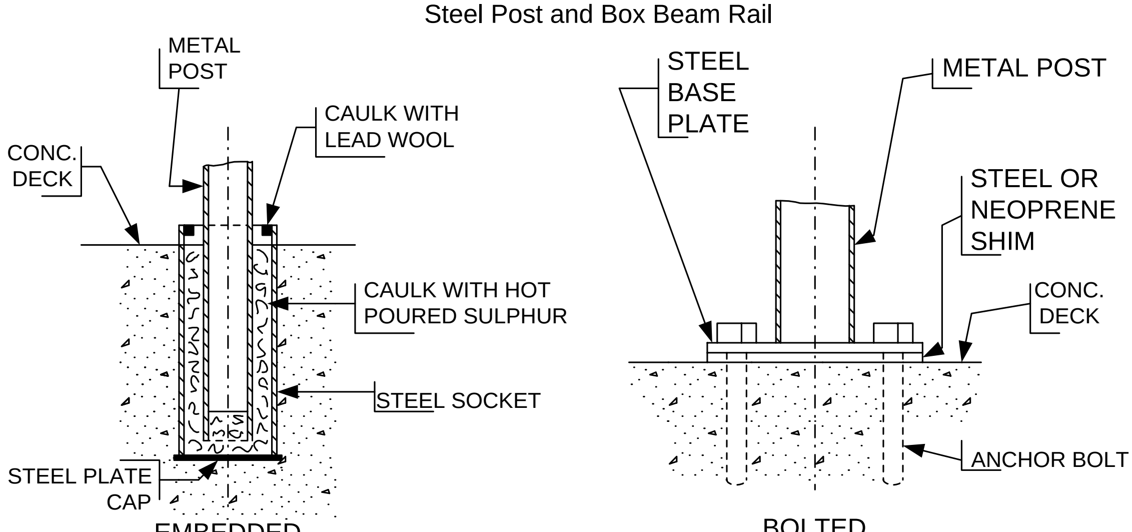
Figure 10.1 Railing Systems (cont'd)



Wood Post and Steel Flex-Beam Rail

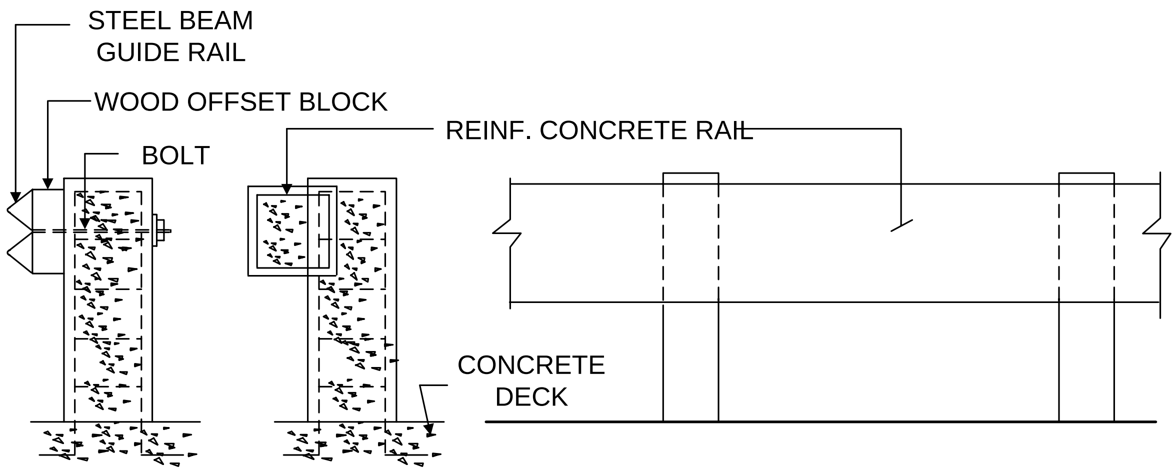


Steel Post and Box Beam Rail

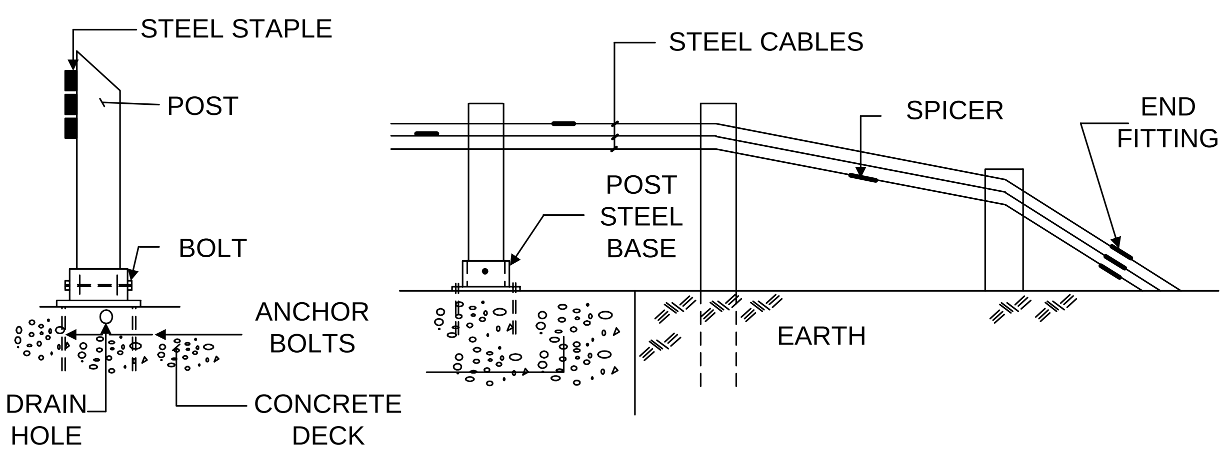


Metal Post Anchorage Details

Figure 10.1 Railing Systems (cont'd)



Concrete Post with Steel Flex-Beam and with
Concrete Rail



Wood Post and Steel Cable

Figure 10.1 Railing Systems (cont'd)

SECTION 11 - STRUCTURAL STEEL COATINGS

CONTENTS

11.1 STRUCTURAL STEEL COATINGS

Structural steel coatings are to be considered as primary or secondary components based upon the designation of the component that is coated. The following coatings and coating systems have been used on provincial steel structures (References 1 to 5).

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

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

- red lead primer;
- light grey second coat;
- green top coat;

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

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

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

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

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

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

(d) **Aluminum-Filled Epoxymastic System**

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

- two coats of aluminum coloured epoxy mastic.

(e) **Inorganic-Zinc/Epoxy/Urethane System**

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

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

(f) **Epoxy-Zinc/Epoxy/Urethane System**

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

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

(g) **Inorganic Zinc/Acrylic/Acrylic**

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

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

(h) **Epoxy-Zinc/Acrylic/Acrylic**

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

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

(i) **High Build Alkyd System**

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

- yellow zinc chromate primer, one or two coats;

- green high build alkyd top coat (for handrails); or
- grey high build alkyd topcoat (for other steelwork).

(j) **Hot Dip Galvanizing**

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

(k) **Metallizing**

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

(l) **Coal Tar Epoxy**

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

(m) **Coal Tar for Piles**

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

11.1.1 MATERIAL DEFECTS OF COATINGS

Material defects are as given in Section 2.

11.1.2 PERFORMANCE DEFECTS OF COATINGS

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

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

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

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

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

11.2 REFERENCES

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

2. SSPC Painting Manual, Volume 2 (4th Edition), Good Painting Practice, SSPC the Society for Protective Coatings, 2002.

3. SSPC Painting Manual, Volume 2 (8th Edition), Systems and Specifications, SSPC the Society for Protective Coatings, 2002.

4. Ridley, Grant, "Laboratory Evaluation of Low VOC Coating Systems for Abrasive Blast Cleaned Steel", Nov. 1993, Internal Report, Ministry of Transportation, Chemical Section, Material Engineering and Research Office, Building C, 1201 Wilson Avenue, Downsview.

5. Ministry of Transportation Structural Steel Coating Manual, 2003 Revised Version.

SECTION 12 - SIGNS

Contents

12.1 SIGNS

The signs most commonly used to indicate restrictions at structures are described below and shown in Figure 12.1. Where signs are available in two sizes, the oversize signs are used on Provincial Highways. They may also be used on other equally important high speed roadways or at locations where greater visibility or impact of the sign is required.

A full description of these signs and their application is contained in References 1, 2 and 3.

a) Narrow Structure Signs

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

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

It is available in two sizes.

Hazard Markers shall be used with the narrow structure signs.

b) One Lane Signs

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

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

c) One lane Only When Used by Trucks Signs

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

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

d) Hazard Marker Signs

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

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

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

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

e) Low Clearance Signs

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

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

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

f) Maximum Weight Signs

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

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

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

g) Others

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

12.1.1 DEFECTS OF SIGNS

The following are some of the typical defects in signs:

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

12.2 REFERENCES

1. Manual of Uniform Traffic Control Devices for Ontario, Division 5.

2. The Highway Traffic Act - Government of Ontario

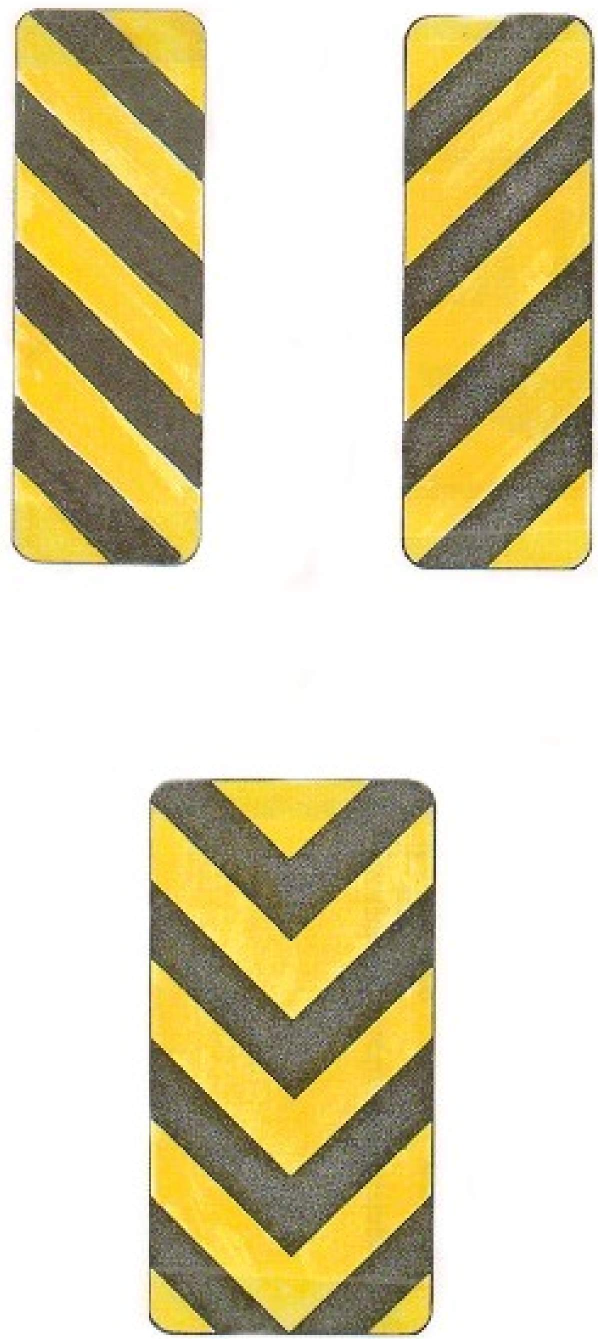
3. Ministry Directive B-43 - Maximum Weight On Bridges Sign

(75 x 75) cm or (90 x 90) cm
(a) Narrow Structure Sign

(b) One Lane Sign

(90 x 90) cm
(c) One Lane Only When Used by Trucks Sign

Figure 12.1 Signs



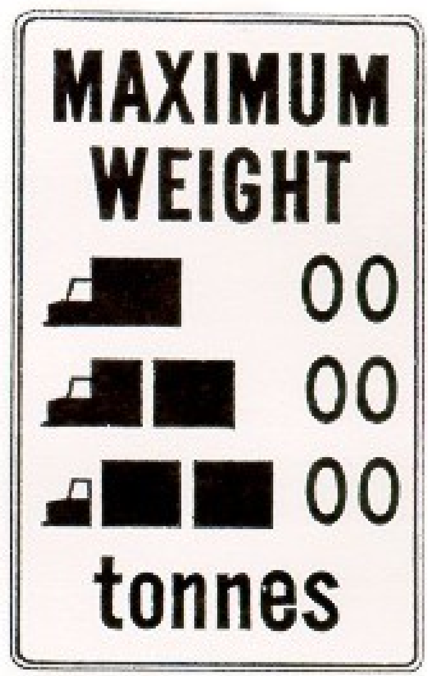
(d) Hazard Marker Signs

Figure 12.1 Signs (cont'd)

(60 x 90) cm
Clearance Sign

(60 x 60) cm or(90 x 90) cm
Advance Clearance Sign

(e) Low Clearance Signs



Single Posting Sign

Multiple Posting Sign

(f) Maximum Weight Signs

Figure 12.1 Signs (cont'd)

SECTION 13 - UTILITIES

Contents

13.1 UTILITIES

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

- water mains
- gas mains
- Bell ducts
- hydro lines

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

13.1.1 DEFECTS OF UTILITY ATTACHMENTS

The following are some typical defects of utility attachments:

- loose, broken or missing components;
- corrosion;
- mechanical damage;
- other visually apparent defects which may cause the attachment(s) to fail resulting in loss of support.

SECTION 14 - LIVE LOADS

Contents

14.1 LIVE LOADS AND POSTING PROCEDURES

This section gives historical information on design and evaluation live loads.

14.2 DESIGN LIVE LOADS

Design live loads from 1917 to present date are shown in Table 14.2 (References 1, 2, 3, 4, 5, and 6).

Design live loads prior to 1917 are not documented. In general, truck loads of 15 tons or less were used depending on the age of the bridge and the class of highway.

The time periods in Table 14.2 refer to the years during which a particular loading was widely used in Ontario. The higher loads were normally used first for the major highways and later introduced on the other road systems.

For example, HS20-16 was first used in 1953 for bridges designed for the Trans Canada Highway followed in 1956 for bridges designed for Provincial Highways. By 1960 it was being used for all bridges designed for the Municipalities as well, except a few in remote areas.

Similarly, bridges on Provincial Highways have been designed by OHBDC since 1979, whereas, most bridges owned by the municipalities are still being designed to HS20-16.

The design loads are documented to provide the inspectors with experience in relating actual loading conditions to design loads.

14.3 EVALUATION LOADS

Evaluation loads, Table 14.3, were introduced in Ontario in 1979. Prior to that evaluation of bridges for load carrying capacity was normally based on the design loads.

14.4 REFERENCES

1. General Plans for Steel Highway Bridges
   The Department of Public Highways, Ontario, 1917
2. General Specifications for Steel Highway Bridges
   The Department of Public Highways, Ontario, 1923
3. General Specification for Highway Bridges. Ontario - 1935
4. Design of Bridges, CSA Standard S6. Canadian Standard Association
5. Standard Specification for Highway Bridges. AASHTO
6. Ontario Highway Bridge Design Code - 1979, 1983
   Ministry of Transportation and Communications

Date	Class of Highway	Truck Loads	Axle Loads and Spacing	Distributed Loads
1917 - 1922 Ontario	Class A	15 tons	5 — 10tons 10'	100 lb./ft^2 over full width of deck.
1923 - 1934 Ontario	Class A Main and County Roads	15 tons	5 — 10 tons 10'	-Spans up to 100' -100 lb./ft.^{2} -Spans 100' to 200' -100 to 80 lb./ft.^{2} -Spans over 200' - 80 lb./ft.^{2}
	Class B Rural Roads	10 tons	3.33 — 6.67 tons 10'	-Spans up to 100' - 80 lb./ft.^{2} -Spans 100' to 200' - 80 to 50 lb./ft.^{2} -Spans over 200' - 50 lb./ft.^{2}
	Class C	20 tons	6.67 — 13.33 tons 10'	-Spans up to 30' - 135 lb./ft.^{2} -Spans 30' to 100' - 135 to 100 lb./ft.^{2} -Spans 100' to 200' - 100 to 80 lb./ft.^{2} -Spans over 200' - 80 lb./ft.^{2}

Table 14.2 - DESIGN LIVE LOADS

Date	Class of Highway	Truck Loads	Axle Loads and Spacing	Distributed Loads
1935 - 1952 Ontario	H 20	20 tons	4 / 16 tons 14'	-Spans up to 100' - 100 lb./ft.^{2} -Spans 100' to 200' - 100 to 80 lb./ft.^{2} -Spans over 200' - 80 lb./ft.^{2}
	H 15	10 tons	3 / 12 tons 14'	-Spans up to 100' - 90 lb./ft.^{2} -Spans 100' to 200' - 90 to 70 lb./ft.^{2} -Spans over 200' - 70 lb./ft.^{2}
	H 10	20 tons	2 / 8 tons 14'	-Spans up to 100' - 80 lb./ft.^{2} -Spans 100' to 200' - 80 to 60 lb./ft.^{2} -Spans over 200' - 60 lb./ft.^{2}
1953 - 1978 CSA Standard -S6 AASHTO	HS 20 - 44	36 tons	4 / 16 / 16 tons 14' 14'	640 lb./linear foot of load lane + Concentrated load of 18,000lb. for moment, 26,000 lb. for shear.
	HS 15 - 44	27 tons	3 / 12 / 12 tons 14' 14'	3/4 of HS 20 - 44 load.

Table 14.2 (con't) - DESIGN LIVE LOADS

Date	Class of Highway	Truck Loads	Axle Loads and Spacing	Distributed Loads
1953 - 1978 (con't)	H 20	20 tons	4 — 16 tons; 14'	Same as HS 20 - 44
	H 15	10 tons	3 — 12 tons; 14'	3/4 of HS 20 - 44
	H 10	20 tons	2 — 8 tons; 14'	1/2 of HS 20 - 44
1979 - OHBDC	A, B, and C	700 kN	60, 140, 140, 200, 160 kN; 3.6, 1.2, 6, 7.2 m	70% of Truck + 10 kN/m for Class A 9 kN/m for Class B 8 kN/m for Class C

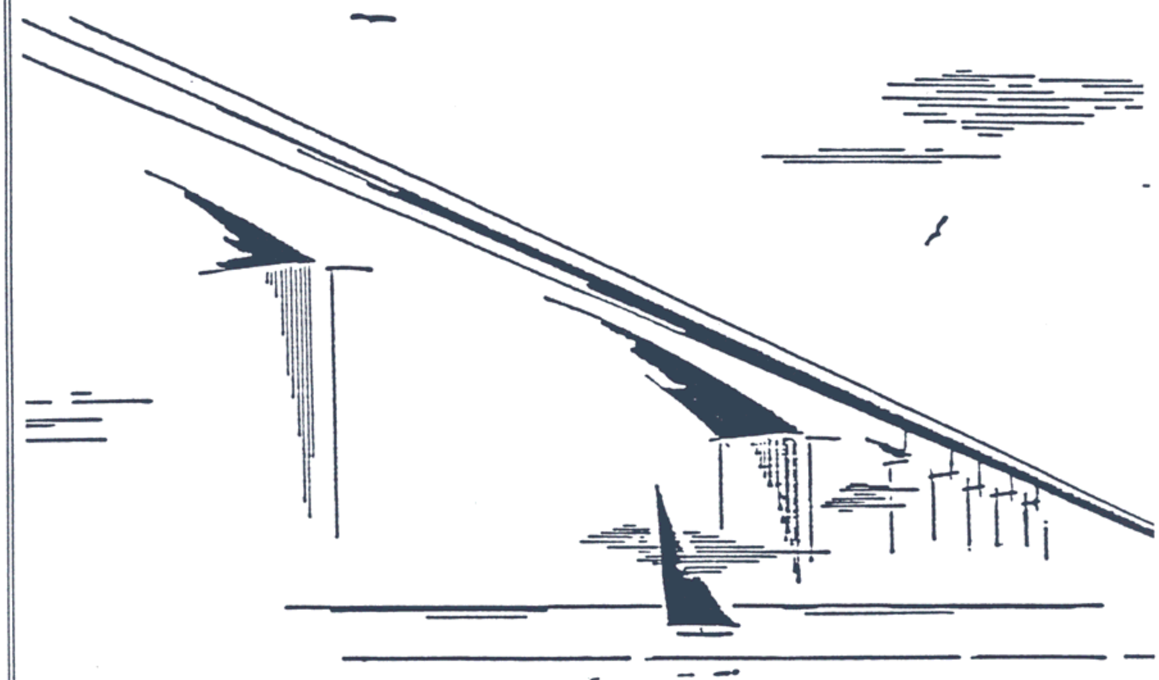
Table 14.2 (con't) - DESIGN LIVE LOADS

Date	Class of Highway	Truck Loads	Axle Loads and Spacing	Distributed Loads
1979 - OHBDC	Level 3	700 kN	Same as design load	- Same as design loads
Evaluation Levels	Level 2	540 kN	60, 140, 140, 200kN 3.6m, 1.2m, 6m	- 70% of level 2 truck + 9 kN/m for Class A 8.1 kN/m for Class B 7.2 kN/m for Class C
	Level 1	340 kN	60, 140, 140 3.6m, 1.2m	- 70% of level 1 truck + 7.5 kN/m for Class A 6.75 kN/m for Class B 6.0 kN/m for Class C

Table 14.2 (con't) - DESIGN LIVE LOADS

Ontario

Ministry of Transportation



ONTARIO

STRUCTURE INSPECTION MANUAL

Part 1 - Technical Information

Part 2 – Detailed Visual Inspections

PART 2 - DETAILED VISUAL INSPECTIONS

CONTENTS Page

SECTION 1 - OVERVIEW OF VISUAL INSPECTIONS

Contents Page

1.1 QUALIFICATIONS OF INSPECTORS

Detailed visual inspections of structures should be carried out by:

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

1.2 RESPONSIBILITIES OF INSPECTORS

The main responsibilities of inspectors are:

- Inspecting all elements that comprise the structure (See Sections 2 and 3)
- Recording all areas of material defects for each element, and categorising them under a defined Condition State (See Section 4)
- Identifying suspected performance deficiencies (See Section 5)
- Noting areas of the structure where routine maintenance is required (See Section 6)
- Making recommendations for repairs and rehabilitation of the structure (See Section 7)
- Indicating the suggested time frame or urgency of the proposed work (See Section 7)
- Identifying additional detailed investigations that are required (See Section 7 and Part 3)

1.3 SAFETY REQUIREMENTS

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

1.4 INSPECTION EQUIPMENT

1.4.1 STANDARD EQUIPMENT CARRIED BY INSPECTORS

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

- Binoculars
- Camera and Film(s) or Digital Camera
- Chalk, Markers and Paint Markers
- Inspection Forms and Clip Boards
- Flashlight (focussing type)
- Length of Chain (2 m)
- Light Chipping Hammer
- Measuring Tape (3 m)
- Measuring Tape (30 m)
- "Workers Ahead" signs
- Mirror on a Swivel Head with an Extension Arm
- Plumb Bob
- Pocket Knife or Multi-tool
- Range Poles
- Safety Belts and Lanyard, Boots, Hat, Gloves, Vest, Flotation Vest
- Safety Cones and Flashing Light
- Scraper
- Screwdriver (large)
- Sounding Line (lead line)
- Straight Edge (1 m)
- Air Thermometers
- Wire Brush
- Re-chargeable Drill with Bits
- Grinder
- Wood Borer and Treated Plugs
- Eye Level and Hand Level
- String-line
- Other Equipment as required

1.4.2 SPECIAL EQUIPMENT REQUIREMENTS

Certain locations on a structure may not be accessible for inspection without special equipment. Inspectors should prearrange with the appropriate parties, for the use of the special equipment such as:

- Boat or Barge
- Extension or Folding Ladder (3.5 m)
- Scaffolds - mobile, cable supported or stationary
- "Snooper" or "Cherry Picker" -truck mounted inspection bucket on a hydraulically operated boom off a truck, such as the Ministry's "BridgeMaster"
- Traffic Protection

1.5 SYSTEMATIC INSPECTION PROCEDURES

1.5.1 PREPARATION PRIOR TO FIELD INSPECTION

The inspector shall:

- Obtain and review existing records of the structure prior to field work, including design and "as-built" drawings, previous inspection reports, correspondence and details of repairs, rehabilitations or modifications carried out after original construction. It is often useful for the inspector to take to the field a one or two page summary of general inventory data and information on previous rehabilitation work. See Section 7 for a sample of this type of inventory data.

- Prepare inspection forms, (See Section 7) for each structure to be inspected. An individual inspection report can be built up, for any structure, by selecting the elements required to completely describe the structure under consideration (See Section 2).

- Record dimensions and calculate the quantities for the bridge elements under consideration as described in Section 3. This information should be summarized on Page 4 in the “Element Data” section of the inspection form (See Section 7). In certain cases, elements shall be divided into sub-elements as indicated in Section 2.

- Decide the time schedule for the inspection and any required special equipment, including traffic protection devices.

- Make arrangements for special equipment and traffic control devices, if required.

- Obtain permission from the railway company if the bridge is over railway tracks, and mobile platforms or other special equipment is going to be used in the track area.

1.5.2 SITE INSPECTION

The inspector shall:

- **Complete a brief overview inspection of the site to:**
  - **Assess the overall integrity of the structure and identify areas where more detailed examination may be required**
  - **Observe the bridge under truck loading and identify any abnormal flexibility, deflections or noises (rattling or vibration of members, etc)**
  - **Look for abnormal deflections, settlements or rotations by looking along the rail or barrier wall or other members**

- **Identify obstacles that may either interfere with the inspection or indicate a need for additional special equipment**.

- Discuss inspection procedures with the foreman of the traffic crew so that adjustments, lane closures and traffic detours, etc. are timed to suit inspection needs.

- Check that all signs, temporary barriers, protective screens, etc. are in place.

- Once the site has been secured, the inspection of each element (as selected in Section 1.5.1) shall proceed in a systematic fashion (top to bottom of structure or bottom to top) by completing the various parts of the inspection form. (See Section 7). Material defects, performance deficiencies, maintenance needs, recommended work and time frame for work shall be noted for each element.

- The inspector has the choice of inspecting all the spans of a structure together or "span by span". If the condition of each span varies considerably from one span to the next, then the inspector should inspect each span separately. Element data would then be recorded separately for each span. Note that if the "span by span" option is chosen, element dimensions and quantities should be recorded for the span under consideration only.

- In general, if several elements of the same type exist for one structure (e.g. Piers, abutments), one "Element Data" table can be used unless the condition of each of the elements varies considerably. If element condition does vary, separate "Element Data" tables should be used and the "Location" part of the inspection form should be filled in to distinguish one element from the next (e.g. North Abutment and South Abutment).

    - Sub-elements, as defined in Section 2, should be used in dividing up the structure, calculating quantities and during the inspection.

    - If elements are changed or added in the field, element quantities must be adjusted accordingly.

- Record observations and make sketches where appropriate.

- Take photographs to adequately describe the structure and the defects found. In general, the following photographs should be taken:

    - One photograph which clearly shows the deck cross-section and features such as number of traffic lanes, curbs and sidewalks, medians and railing system. *Note: This photograph is normally taken from the approach roadway looking along the length of the bridge.*

    - One photograph of the elevation of the structure which clearly shows the number of spans and superstructure type.

    - One photograph of the underside (soffit) which shows the type and number of main superstructure element(s).

    - Individual photographs should be taken of <u>all areas in a poor condition state</u> (areas with severe defects and deterioration). These photographs should be taken at sufficiently close range such that the type, location and extent of the defects are clearly visible and apparent. *Note: Where there are no areas of severe deterioration in an element, then a photograph should be taken showing a typical area which represents the worst condition state in that element.*

- Check if the structure and its elements are built in accordance with existing available information and record any significant discrepancies, so that existing records can be revised accordingly. If changes have taken place as the result of rehabilitation work, element dimensions and quantities should be updated.

- Identify additional detailed investigations that are required.

1.5.3 POST INSPECTION PROCEDURES

The inspector shall:

- Make sure all inspection equipment and temporary traffic control devices are removed from the site and the site is left in workmanlike order.

- Ensure the appropriate follow-up action is taken for any Suspected Performance Deficiencies noted during the inspection.

- Submit Maintenance Needs list to maintenance crew for action.

- Ensure additional investigations are initiated in the timeframe recommended.

- Write all necessary follow-up correspondence and reports.

SECTION 2 – ELEMENT LIST

The first step in performing a detailed visual inspection is to divide the structure into individual elements. Bridge components, as described in Part 1 of this manual, have been grouped into elements where convenient. Although primary, secondary and auxiliary components are described in Part 1, for inspection purposes, no distinction is made between these types of components. Table 2.1 lists the standard elements available for each element group. Table 2.1 also gives the standard unit of measurement for quantities for each element and the appropriate Condition State Table for categorising material defects. Table 2.2 lists the elements that are typically required for the most common types of structures. It should be noted that this list is for guidance only. The actual element list should be customised to suit the structure being inspected. For an explanation of what components of the structure are included under each element category, refer to Table 3.1 in Section 3. The following general guidelines should be followed when selecting elements:

- Similar element types, within the same Element Group, should be grouped together, and a separate "Element Data" table should be filled out for each element type (e.g. similar bearing types, diaphragm types, etc).

- If element condition varies for similar element types, separate "Element Data" tables" should be used and the "Location" part of the inspection form should be filled in to distinguish one element from the next (e.g. North Abutment and South Abutment).

- Elements should be divided into "sub-elements", as shown in Table 2.2. The definitions for sub-elements are given in Table 3.1. A separate "Element Data" table should be filled out for each sub-element. The following sub-elements should be used:

  - For structures with expansion joints, an "End" element must be used for the superstructure element(s) (deck, girder, etc). Each "End" shall be rated separately from the "Middle" portion of that element. An "end" element is defined as having a length of 1 to 3 metres. The length should be selected based on the extent of deterioration in the element end. An assumption of 2 metres can be made initially and adjusted in the field afterwards. If the length of the end element is changed, the quantity calculations, as described in Section 3, should also be adjusted accordingly.

  - For deck soffits, "Exterior" cantilevers shall be rated separately from the "Interior" of the soffit.

  - For diaphragms, floor beams and stringers, "End" and "Intermediate" sub-elements shall be used.

  - For barrier/parapet walls, the "Interior" face shall be rated separately from the "Exterior" face.

- At this stage, a decision should also be made regarding the overall process for inspecting the bridge. Section 1.5.2 describes the criteria for selecting whether the bridge should be inspected as a whole or span by span.

- The element list in Table 2.1 includes the most common bridge components. If a particular component is not found in the element list, the most appropriate (closest match) element should be selected from the list. The "Location" part of the inspection form can also be used when trying to identify non-standard elements.

Table 2.1: Element List and Condition State Cross Reference Table

Element Group	Element Name[6,7,8]	Unit for Quantity[1,2,3, 4]	Applicable Condition State Table Number [5]
Abutments	Abutment walls	Sq.m.	4.5, 4.11, 4.19
	Ballast walls	Sq.m.	4.5, 4.11, 4.19
	Bearings	Each	4.2
	Wingwalls	Sq.m.	4.5, 4.11, 4.19
Approaches	Approach slabs	Sq.m.	4.5, 4.6
	Curb/gutters	m.	4.5
	Drainage System	All	4.7
	Sidewalk	Sq.m.	4.5
	Wearing surface	Sq.m.	4.1, 4.5, 4.6
Barriers	Barrier/Parapet Walls	Sq.m.	4.5
	Hand Railings	m.	4.17
	Posts	Sq.m. (each if Wood)	4.5, 4.16, 4.19
	Railing Systems	m.	4.17, 4.19
Beams/Main Longitudinal Elements	Diaphragms	Each (Sq.m if Concrete)	4.5, 4.15, 4.16, 4.19
	Floor beams	Sq.m.	4.5, 4.16, 4.19
	Girders	Sq.m.	4.5, 4.15, 4.16, 4.19
	Inside boxes (sides & bottom)	Sq.m.	4.5 , 4.15
	Stringers	Each	4.5 , 4.16, 4.19
Bracing	Bracing	Each	4.15, 4.16, 4.19
Coatings	Railing Systems / Hand Railings	Sq.m.	4.3
	Structural Steel	Sq.m.	4.4
Culverts	Barrels	Sq.m.	4.5, 4.14
	Inlet Components	Sq.m.	4.5
	Outlet Components	Sq.m.	4.5
Decks	Deck Top	Sq.m.	4.5, 4.6, 4.19
	Drainage System	All	4.7
	Soffit – Inside Boxes	Sq.m.	4.5
	Soffit – Thick slab	Sq.m.	4.5
	Soffit – Thin Slab	Sq.m.	4.5, 4.19
	Wearing Surface	Sq.m.	4.1
Embankments & Streams	Embankments	All	4.8
	Slope protection	All	4.13
	Streams and Waterways	All	4.18
Foundations	Foundation (below ground level)	N/A	Rate performance only.
Joints	Armouring/retaining devices	m.	4.9
	Concrete end dams	Sq.m	4.5
	Seals/sealants	each	4.10
Piers	Bearings	Each	4.2
	Caps	Sq.m.	4.5, 4.11, 4.16, 4.19
	Shafts/columns/Pile Bents	Sq.m.	4.5, 4.11, 4.16, 4.19
Retaining walls	Barrier Systems on walls	Sq.m.	4.5, 4.17, 4.19
	Walls	Sq.m.	4.5
Sidewalks/curbs	Curbs	Sq.m.	4.5

Element Group	Element Name[6,7,8]	Unit for Quantity[1,2,3, 4]	Applicable Condition State Table Number [5]
	Sidewalks and medians	Sq.m.	4.5
Signs	Signs	Each	4.12
Trusses/Arches	Bottom chords	Sq.m.	4.5, 4.16, 4.19
	Connections	Each	4.16, 4.19
	Top chords	Sq.m.	4.5, 4.16, 4.19
	Verticals/diagonals	Sq.m.	4.5, 4.16, 4.19

Notes: 1 – For “All”, place the entire component (100%) in one condition state.
2 – For “Each”, give the number of occurrences of the component in each state.
3 – For cracks in concrete, estimate repair area (4m of crack = 1 sq. m of repair).
4 – For cracks in steel, estimate required repair area.
5 – Tables given are typical for element. Use appropriate table for applicable material. (See Section 4).
6 – Sub-elements (End/Middle) to be used for the following elements at expansion joint locations: Deck Top, Girders, Inside Boxes
Sub-elements (End/Intermediate) to be used for the following elements at expansion joint locations:: Floor Beams, Stringers, Bracing and Diaphragms
Sub-elements (End/Interior/Exterior) to be used for Soffits
Sub-elements (Interior/Exterior) to be used for Barrier/Parapet Walls
7 – For an explanation of which bridge components are included in each element, see Table 3.1.
8 – Similar element types should be grouped together (e.g. I-girders, x-frames, etc.)

Table 2.2: Element List for Each Bridge Type*

Element Group	Element Name	Sub-element	Slab on I-girder (Steel)	Slab on I-girder (Concrete)	Slab on Box-girder (steel)	Slab on Box-girder (concrete)	Post-tensioned deck (Rectangular voids)	Post-tensioned deck (Circular voids)	Solid Slab	Truss	Culvert	Rigid Frame
Abutments	Abutment walls		X	X	X	X	X	X	X	X		X
	Ballast walls		X	X	X	X	X	X	X	X		
	Bearings		X	X	X	X	X	X	X	X		
	Wingwalls		X	X	X	X	X	X	X	X	X	X
Approaches	Approach slabs		X	X	X	X	X	X	X	X		X
	Curb/gutters		?	?	?	?	?	?	?	?	?	?
	Drainage System		X	X	X	X	X	X	X	X	?	X
	Sidewalk		?	?	?	?	?	?	?	?	?	?
	Wearing surface		X	X	X	X	X	X	X	X	?	X
Barriers	Barrier/Parapet Walls	Interior/ Exterior (for faces of barrier)	X or	X or	X or	X or	X or	X or	X or	X or	X or	X or
	Hand Railings		?	?	?	?	?	?	?	?	?	?
	Posts		?	?	?	?	?	?	?	?	?	?
	Railing Systems		X	X	X	X	X	X	X	X	X	X
Beams / Main Longitudinal Elements (MLE's)	Diaphragms											
		End	X	X	X	X						
		Intermediate	X	?	X	?						
	Floor beams	End								X		
		Intermediate								X		
	Girders		X or	X or	X or	X or						
		End / Middle	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)						
	Inside boxes				X or	X or	X or					
		End/Middle			X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)					

Element Group	Element Name	Sub-element	Slab on I-girder (Steel)	Slab on I-girder (Concrete)	Slab on Box-girder (steel)	Slab on Box-girder (concrete)	Post-tensioned deck (Rectangular voids)	Post-tensioned deck (Circular voids)	Solid Slab	Truss	Culvert	Rigid Frame
	Stringers	End								X		
		Intermediate								X		
	Bracing	End								X		
		Intermediate								X		
Coatings	Barrier Systems / Hand Railings		?	?	?	?	?	?	?	?	?	?
	Structural Steel		X (Not applicable for ACR steel) or		X (Not applicable for ACR steel) or					X (Not applicable for ACR steel) or	X (Not applicable for ACR steel) or	
		End/Middle	X (only with exp. Joints)		X (only with exp. Joints)					X (only with exp. Joints)	X (only with exp. Joints)	
Culverts	Barrels										X	
	Inlet Components										X	
	Outlet Components										X	
Decks	Deck Top		X	X	X	X	X	X	X	X		X
	Drainage System		X	X	X	X	X	X	X	X		
	Soffit – Inside Boxes				X or	X or	X or					
		End / Middle			X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)					
	Soffit – Thick slab (Post-tensioned decks and Rigid Frames)											X
		End					X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)			
		Exterior					X	X	X			X
		Interior					X	X	X			X
	Soffit – Thin Slab (Slab on I or Box Girders)	End	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)				X (only with exp. Joints)		
		Exterior	X	X	X	X				?		
		Interior	X	X	X	X				X		

	Wearing Surface		X	X	X	X	X	X	X	X	X	X
Element Group	**Element Name**	**Sub-element**	**Slab on I-girder (Steel)**	**Slab on I-girder (Concrete)**	**Slab on Box-girder (steel)**	**Slab on Box-girder (concrete)**	**Post-tensioned deck (Rectangular voids)**	**Post-tensioned deck (Circular voids)**	**Solid Slab**	**Truss**	**Culvert**	**Rigid Frame**
Embankments and Streams	Embankments		X	X	X	X	X	X	X	X	X	X
	Slope protection		X	X	X	X	X	X	X	X	X	X
	Streams and Waterways		? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	X	? (only for water crossing)
Foundations	Foundation (below ground level)		X	X	X	X	X	X	X	X	X	X
Joints	Armouring / retaining devices		?	?	?	?	?	?	?	X		
	Concrete end dams		?	?	?	?	?	?	?	X		
	Seals / sealants		?	?	?	?	?	?	?	X		
Piers (only for multi-span structures)	Bearings		X	X	X	X	?	?	?	X		
	Caps		?	?	?	?	?	?	?	?		?
	Shafts/Columns/Pile Bents		X	X	X	X	X	X	X	X	X	X
Retaining walls	Barrier Systems on Walls	Interior / Exterior (for faces of barrier)	?	?	?	?	?	?	?	?	?	?
	Walls		?	?	?	?	?	?	?	?	?	?
Sidewalks/curbs	Curbs		?	?	?	?	?	?	?	?		?
	Sidewalks and medians		?	?	?	?	?	?	?	?		?
Signs	Signs		?	?	?	?	?	?	?	?	?	?
Trusses/Arches	Bottom Chords									X		
	Connections									X		
	Top chords									X		
	Verticals / Diagonals									X		

Notes:

* = It should be noted that this list is for guidance only. The actual element list should be customised to suit the structure being inspected.
X = Element Required
X or = Element or subsequent element must be chosen (only 1 of the choices needs to be selected) e.g. Barrier /parapet wall or Railing System
? = May be applicable if component exists (e.g. Exp. Joint)

SECTION 3 – ELEMENT QUANTITY CALCULATIONS

As described earlier, this version of the Ontario Structure Inspection Manual is based on the "severity and extent" philosophy. In order to estimate rehabilitation needs, quantities of material defects in each Condition State must be recorded for each element. To determine the most suitable rehabilitation option, the recorded defect quantity must be compared to the overall quantity for that element. The Structure Rehabilitation Manual describes how to select the appropriate rehabilitation option based on the extent of material defects.

Table 3.1 describes how to calculate dimensions (length, width, height) and quantities for the various types of elements. In general, dimensions can be obtained from structural drawings, however, these values should be verified in the field (e.g. curb height may have been reduced after a resurfacing operation). It should be noted that the quantity calculation is approximate in some cases (e.g. surface area of a girder), but is accurate enough to be used in estimating rehabilitation needs. In general, quantities are calculated for one element (e.g. girder) and then the Total Quantity is calculated by multiplying the quantity by the number of that type of element (Count).

In an effort to simplify the inspection process, the parts of the structure that are likely to be in similar condition are grouped together. This is accomplished by using "sub-elements", as described in Section 2. When sub-elements are used, element quantities shall be calculated for each sub-element, as described in Table 3.1 and Figures 3.1 – 3.4.

For elements that are partially buried, quantities should be calculated for the part of the element that is visible above the ground (e.g. pile bents). For all other elements, the quantity shall be based on the total area of the element as shown on the plans. (e.g. ballast wall). When inspecting an element that is partially hidden (e.g. ballast wall), the quantity of material defects should be estimated based on the portion that is visible. For example, a ballast wall at an expansion joint location may show signs of severe defects if the expansion joint has been leaking. If the visible part of the wall is in "Poor" Condition, the inspector can probably assume that the remainder of the wall is in similar condition.

Table 3.1: Procedures for Computing Element Dimensions and Quantities

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
Abutments	Abutment walls		N/A	average width of abutment from wing wall to wing wall	Average top of bearing seat elevation – average top of ground elevation + bearing seat width + visible part of footing	# of abutments (2 max.)	width x height x count	Includes bearing seat width and top of footing (if visible).
	Ballast walls		N/A	average width wing wall to wing wall	For Decks without exp. Joints Average underside of deck soffit elevation – average bearing seat elevation For Decks with exp. joints Top of deck elevation – average bearing seat elevation	# of ballast walls	width x height x count	Quantity includes entire ballast wall even if some areas are not visible due to diaphragms.
	Bearings		N/A	N/A	N/A	Total # of bearings at abutments	count (Units are Each)	
	Wingwalls		average length of wing walls (from 6 bearing to end of approach)	N/A	Average height	# of wingwalls	length x height x count	
Approaches[6]	Approach slabs		Approach slab length	curb to curb width	Thickness	# of approaches	count x width x length	
	Curb/gutters		avg. of length of approach slab	N/A	Min. height of curb	# of curbs (2 per abutment maximum)	count x length (units are m)	
	Drainage System		N/A	N/A	N/A	N/A	Units are All	

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
	Sidewalk		avg. Length of approach slab	avg. width of sidewalk	Min. height of sidewalk curb	# of sidewalks	count x length x (width + height)	
	Wearing surface		Approach slab length	curb to curb width	Thickness	# of approaches	count x width x length	
Barriers	Barrier/Parapet Walls	Interior / Exterior (for faces of barrier)	total length including approaches (to end of approach slabs) for one side	N/A	Barrier height	# of sides (typically 2)	length x height x count	Sub-elements must be used and interior and exterior of barrier/parapet must be rated separately.
	Hand Railings		total length of railing on top of barrier (includes approaches) on one side	N/A	N/A	# of sides	count x length (units are m)	This element is to be used for railings on top of barrier/parapet walls.
	Posts		Length dimension of a post along length of bridge	thickness of post	Height of posts	# of posts	count x 2 (length + width) x height or count if wood (units are Each)	This element is to be used for the post component of open type of railing systems. (Wood posts, concrete posts, end posts, etc).
	Railing Systems		length of 1 steel panel	N/A	Height of barrier	# of panels	length x count (units are m)	This element is to be used for open type of railing systems (steel railing, flex beam, etc)
Beams / Main Longitudinal Elements (MLE's)	Diaphragms		girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual diaphragm segments	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	All Diaphragms. To be used if all diaphragms are of the same type and the deck does not have expansion joints. (See Figure 3.1b)

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
		End[2]	girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual diaphragm segments	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	Diaphragms at support locations (piers, abutments). Similar diaphragm types should be grouped together. (See Figure 3.1b)
		Intermediate	girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual members (braces)	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	All diaphragms in the span(s).
	Floor beams		curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	All floor beams. To be used if all floor beams are of the same type and the deck does not have expansion joints. (See Figure 3.1c)
		End	curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	End floor beams at expansion joint locations. (See Figure 3.1c)
		Intermediate	curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	Intermediate floor beams (See Figure 3.1c)
	Girders		total length (spans + overhangs[3])	*For I girders:* average width of flanges (simple avg.) *For Boxes:* bottom flange width	Girder depth (flange to flange)	# of lines of girders or boxes	*For I girders:* length x count x (height x 2 + width x 3) *For Boxes:* length x count x (height x2+width)	Entire length of girders. To be used if the deck does not have expansion joints. (See Figure 3.1a)

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
		End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	*For I girders:* average width of flanges (simple avg.) *For Boxes:* bottom flange width	Girder depth (flange to flange)	# of lines of girders or boxes	*For I girders:* length x count x (height x 2 + width x 3) *For Boxes:* length x count x (height x 2 + width)	For decks with expansion joints. (See Figure 3.1a)
		Middle	Sum of span lengths + sum of overhangs – sum of "Ends"	*For I girders:* average width of flanges (simple avg.) *For Boxes:* bottom flange width	Girder depth (flange to flange)	# of lines of girders or boxes	*For I girders:* length x count x (height x 2 + width x 3) *For Boxes:* length x count x (height x 2 + width)	To be used in areas away from expansion joints in conjunction with the "end" element. (See Figure 3.1a)
	Inside boxes		total length (spans + overhangs)	bottom flange width	Girder depth (flange to flange)	# of lines of boxes	length x count x (height x 2 + width)	Entire length to be used if deck does not have expansion joints.
		End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	bottom flange width	Girder depth (flange to flange)	# of lines of boxes	length x count x (height x 2 + width)	For decks with expansion joints.
		Middle	Sum of span lengths + sum of overhangs – sum of "Ends"	bottom flange width	Girder depth (flange to flange)	# of lines of boxes	length x count x (height x 2 + width)	To be used in areas away from expansion joints in conjunction with the "end" element. (See Figure 3.1a)
	Stringers		floor beam spacing	average width of flanges	Depth	# of stringers	count (Units are Each)	All stringers. To be used if the deck does not have expansion joints.
		End	floor beam spacing	average width of flanges	Depth	# of stringers	count (Units are Each)	Stringers in end panel at exp. joint locations (See Figure 3.1c)

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
		Intermediate	floor beam spacing	average width of flanges	Depth	# of stringers	Count (Units are Each)	Stringers in intermediate panels
Bracing	Bracing		average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	All Bracings - includes bracing between trusses and lateral bracing between floor system in horizontal plane - vertical plane is considered a diaphragm element (See Figure 3.1b)
		End	average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	Bracings in end panel. (See Figure 3.1b)
		Intermediate	average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	Bracings in Intermediate panel (See Figure 3.1b)
Coatings	Barrier Systems / Hand Railings		N/A	N/A	N/A	N/A	Use Area of corresponding Barrier System element	
	Structural Steel		N/A	N/A	N/A	N/A	Use Area of corresponding element such as girder, floor beams etc.	For all structural steel.
		End	N/A	N/A	N/A	N/A	Use Area of corresponding sub-element such as end of girder, end floor beams etc.	To be used if the corresponding element used “End” elements.
		Middle	N/A	N/A	N/A	N/A	Use Area of corresponding sub-element such as middle of girder, end floor beams etc.	To be used if the corresponding element used “Middle” elements

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
Culverts[5]	Barrels		total length of culvert	Average cell width	Height of cell	# of cells	total interior surface area for one cell x # of cells	Interior surface area includes soffit, walls and bottom slab of culvert if present
	Inlet Components		N/A	N/A	N/A	1	area of all inlet components	Includes all components. (head walls, cut-off walls, aprons, etc)
	Outlet Components		N/A	N/A	N/A	1	area of all outlet components	Includes all components. (head walls, cut-off walls, aprons, etc)
Decks	Deck Top		sum of span lengths + sum of overhangs[3]	overall width (out-to-out)	Deck thickness minimum	N/A	length x width	(See Figure 3.2b)
	Drainage System		N/A	N/A	N/A	N/A	N/A (units are All)	Includes all components such as drains, drain pipes, connecting pipes, etc.
	Soffit – Inside Boxes		sum of span lengths + sum of overhangs[3]	Sum of distance between top flanges inside of boxes (steel or concrete)	N/A	N/A	length x width	The entire soffit length inside the boxes. To be used for decks without expansion joints (See Figure 3.2c)
		End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	Sum of distance between top flanges of boxes (steel or concrete)	N/A	N/A	length x width	For decks with expansion joints (See Figure 3.2c)
		Middle	Sum of span lengths + sum of overhangs – sum of “Ends”	Sum of distance between top flanges of boxes (steel or concrete)	N/A	N/A	length x width	To be used in areas away from expansion joints in conjunction with the “end” element. (See Figure 3.2c).
	Soffit – Thick slab (Post-tensioned decks and Rigid Frames)							

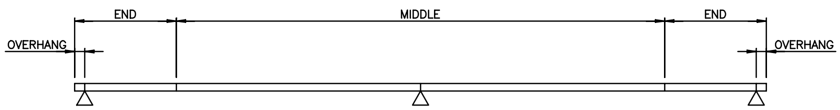
Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
		End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	overall width + fascias	N/A	N/A	length x width	For decks with expansion joints
		Exterior	Sum of span lengths + sum of overhangs – sum of "Ends"	fascias + cantilevers[4]	N/A	N/A	length x width	For Rigid frames, span lengths are from faces of abutments and piers and the cantilever is assumed to be 1m as shown in Figure 3.4. When End elements are used, the length will be reduced by the sum of the End elements. (See Figure 3.2c)
		Interior	Sum of span lengths + sum of overhangs – sum of "Ends"	overall width – cantilevers[4]	N/A	N/A	length x width	For Rigid frames, span lengths are from faces of abutments and piers. When End elements are used, the length will be reduced by the sum of the End elements. (See Figure 3.2c)
	Soffit – Thin Slab (Slab on I or Box Girders)	End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	fascias + exterior cantilevers to flanges + sum of distances between flanges (for boxes use outside of box top flanges only)	N/A	N/A	length x width	For decks with expansion joints
		Exterior	Sum of span lengths + sum of overhangs – sum of "Ends"	fascias + exterior cantilevers to flanges	N/A	N/A	length x width	When End elements are used, the length will be reduced by the sum of the End elements.

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
		Interior	Sum of span lengths + sum of overhangs – sum of “Ends”	sum of distances between flanges (for boxes use outside of box top flanges only)	N/A	N/A	length x width	When End elements are used, the length will be reduced by the sum of the End elements.
	Wearing Surface		Sum of span lengths + Sum of overhangs	Roadway width (curb to curb)	Thickness of wearing surface from drawings	N/A	length x width	
Embankments & Streams	Embankments		N/A	N/A	N/A	N/A	Units are All	
	Slope protection		N/A	N/A	N/A	N/A	Units are All	
	Streams and Waterways		N/A	N/A	N/A	N/A	Units are All	
Foundations	Foundation (below ground level)		N/A	N/A	N/A	N/A	N/A	Foundation is considered to be anything below ground. This element is rated for performance only and not material condition. If top of footing is visible, it should be rated under the Abutment wall or Pier Shaft element.
Joints	Armouring / retaining devices		Overall width (out-to-out) for 1 armouring	N/A	N/A	# of armourings (Typically, 2 per joint x # of joints)	count x length (units are m)	For multi-seal joints, the total length shall include the armouring, separator beams, support beams, etc.
	Concrete end dams		Curb to curb width	width of one side only	N/A	# of end dams (2 per joint x # of joints)	length x width x count	
	Seals / sealants		Overall width of bridge (for 1 seal)	N/A	N/A	# of seals	count (units are Each)	
Piers	Bearings		N/A	N/A	N/A	Total # of bearings at piers	count (Units are Each)	

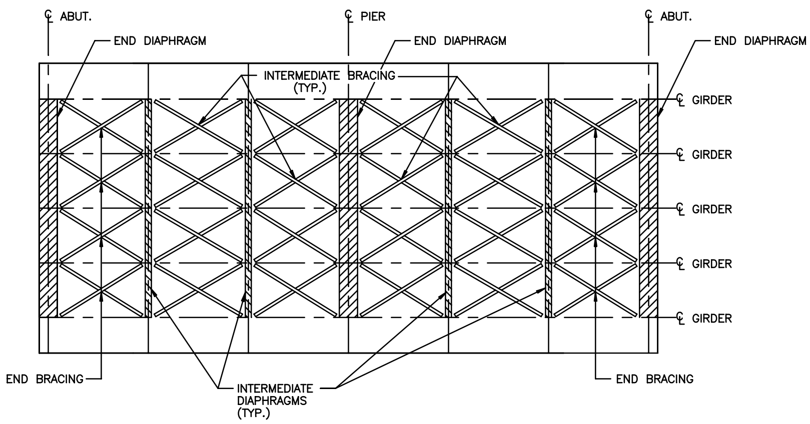
Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
	Caps		Thickness or length of caps parallel to length of bridge	width of cap	Depth or height of cap	# of caps	count x 2 x [(width x height) + (length x height) + (length x width)]	
	Shafts/Columns/Pile Bents		*For Rectangular Shaft or Column:* Thickness parallel to bridge length *For Round Columns , Pipe Piles or Timber Piles:* Diameter *For H-Pile Bents:* web heights	**For rectangular Shaft or Column:** avg. width of shaft or column *For Round Columns , Pipe Piles or Timber Piles:* Diameter *For H-Piles:* flange width	Bearing seat elevation or elevation at bottom of pier cap - top of ground elevation (if under water use stream bed elevation)+ bearing seat width+visible part of footing	# of shafts or # of columns or # of piles	**For Rectangular Shafts or Columns:** 2 x (length + width) x height x count **For Round Columns, Pipe Piles or Timber Piles:** B x width x height x count **For H Piles:** *count x height x (2 x length + 4 x width)*	Note: similar shapes should be combined as an element Includes bearing seat width and top of footing (if visible).
Retaining walls	Barrier Systems on Walls	Interior / Exterior (for faces of barrier)	total length including approaches (to end of approach slabs) for one side	N/A	Barrier height	# of sides (typically 2)	length x height x count	Sub-elements must be used and interior and exterior of barrier/parapet must be rated separately.
	Walls		average length of wall	N/A	Average height of wall	# of walls	length x height x count	
Sidewalks/curbs	Curbs		total length of bridge excluding approaches	avg. width of all curbs	Maximum height (need to verify in field because of resurfacing)	# of curbs	length x (width + height) x count	See Figure 3.3 for definition of sidewalk / median and curb
	Sidewalks and medians		total length of bridge excluding approaches	avg. width of all sidewalks / medians	Maximum height (need to verify in field because of resurfacing)	# of sidewalks / medians	length x (width + height) x count	See Figure 3.3 for definition of sidewalk / median and curb

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity Sq.m[1]	Comments
Signs	Signs		N/A	N/A	N/A	N/A	Units are All	
Trusses/Arches	Bottom Chords		total length of top chord (all panels)	average flange width	Depth of section	# of chords/side = 2 usually	*For I Sections:* quantity = count x length x(height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	
	Connections		N/A	N/A	N/A	# of connections	Count (Units are Each)	Main truss connections
	Top chords		total length of top chord (all panels)	average flange width	Depth of section	# of chords/side = 2 usually	*For I Sections:* quantity = count x length x (height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	
	Verticals / Diagonals		average length of diagonals	average flange width	Depth of section	# of verticals / diagonals for all sides	*For I Sections:* quantity = count x length x (height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	

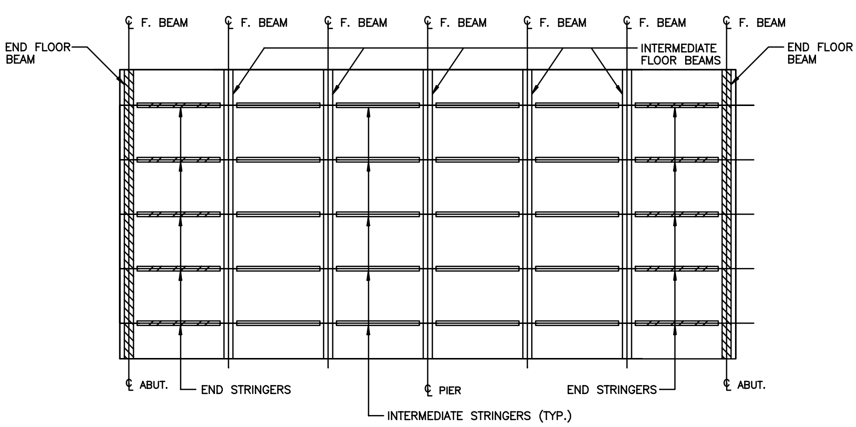
Notes: 1 – Default units are sq.m unless noted otherwise.
2 – End elements are to be used at all expansion joint locations
3 – Overhang = Distance from 6 of Bearing to end of deck (See Figure 3.1a, 3.2a)
4 - Cantilever = See Figure 3.4
5 – Culverts include soil-steel structures
6 – The length of the "approach" should be taken as the length of the approach slab or the length to the end of the wingwalls (whichever is greater).



(a) Girders (Elevation view)

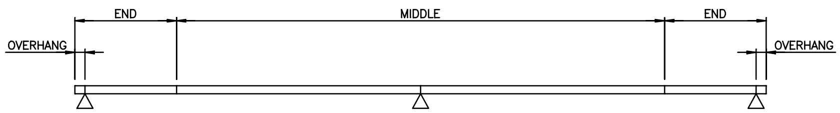


(b) Girders, Diaphragms and Bracing (Plan view)

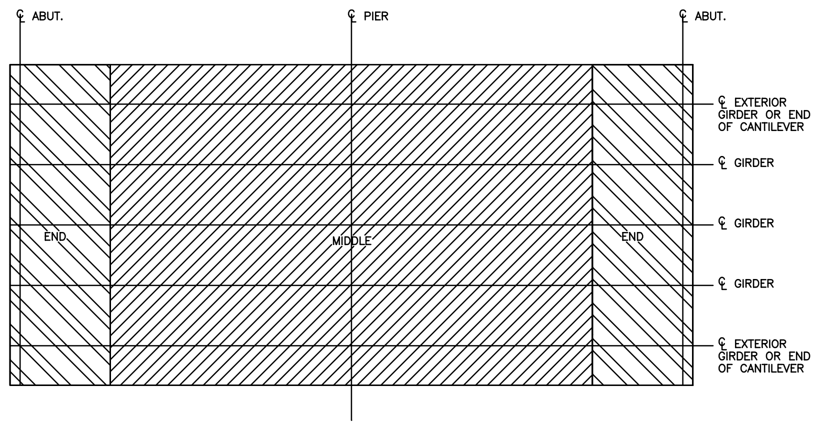


(c) Floor Beams and Stringers

Figure 3.1: Structural Steel Definitions



(a) Deck (Elevation view)



(b) Deck Top

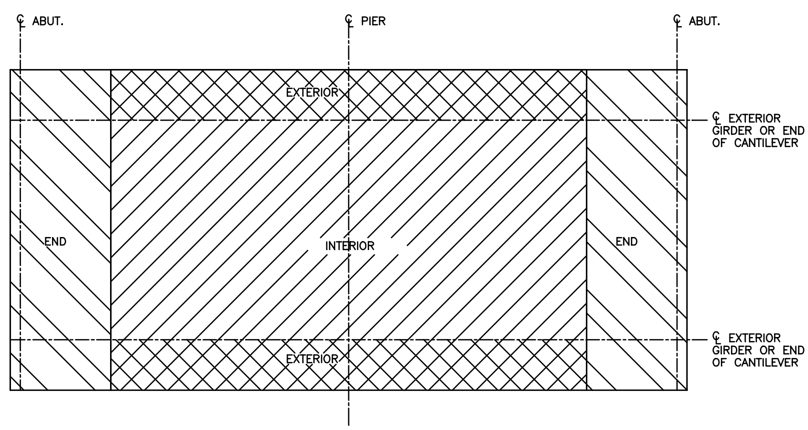


Figure 3.2: Deck Definitions

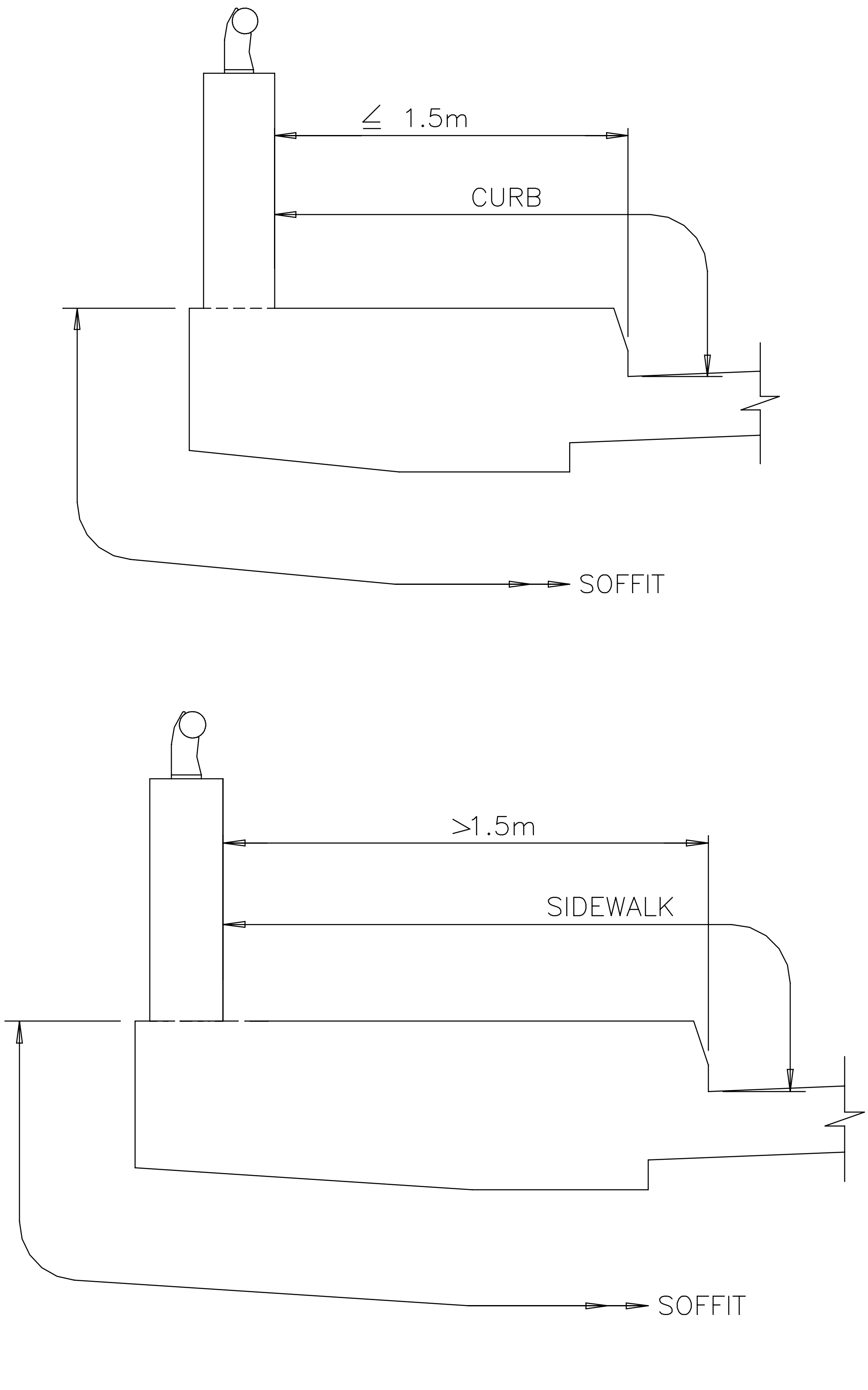


Figure 3.3: Curb and Sidewalk Definitions

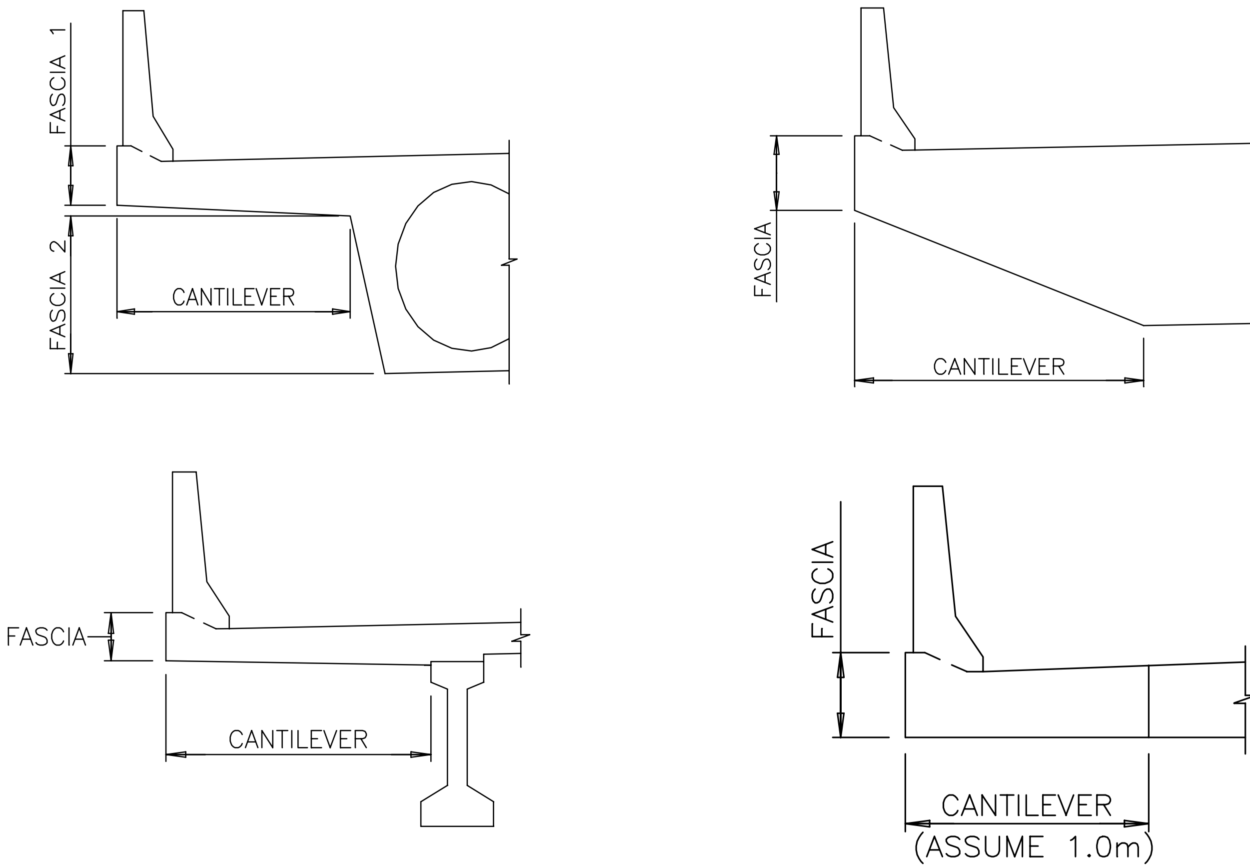


Figure 3.4: Cantilever Definitions

SECTION 4 – MATERIAL CONDITION STATE TABLES

In general, Material Condition States are used to categorize the condition of an element based on the severity of material defects. Four Material Condition States have been defined for bridge elements, namely, Excellent, Good, Fair and Poor. The condition of bridge elements is defined to be in any one or more of these Condition States. At any given time, areas within a bridge element may be in different Condition States, or the whole of the element may be in the same Condition State. For each bridge element, the inspector assesses and records the amount (area, length or unit, as appropriate) of the element in each of the four Condition States. This assessment is based predominately on visual observations, however, some non-destructive testing, such as hammer tapping of concrete for delamination, will be required to determine or verify areas in poor condition. **Where an area in poor condition is noted, the area is to be measured (if practicable), or estimated.**

The importance of recording quantities of defects cannot be over-emphasized. Using rough percentages without some sort of verification will usually lead to a grossly inaccurate estimation of rehabilitation needs. This is especially true in the "Poor" Condition State. Although the extent of defects is still based on visual observations, studies have shown that the recording of actual quantities (square metre or metre) leads to a better estimation of rehabilitation needs.

There are four basic units that are used to describe the material condition of various elements (See Table 2.1):

- ***SQUARE METRE (Area):*** *For many elements, the condition states will be recorded as an area measurement, m^2. For example, a deck element of area 1000 m^2 may have 100 m^2 in excellent condition, 700 m^2 in good condition, 100 m^2 in fair condition and 100 m^2 in poor condition.*

- ***LINEAR METRE (Length):*** *For some elements, such as the expansion joint armouring, the data is recorded by linear metre. For example, an expansion joint armouring of 10 m length may have 0 metres in excellent condition, 3 metres in good condition, 2 metres in fair condition, and 5 metres in poor condition.*

- ***EACH:*** *For some elements, such as bearings, the unit is "each". For example, a bridge with 10 bearings may have 5 bearings in excellent condition, 3 bearings good condition, 1 bearing in fair condition and 1 bearing in poor condition.*

- ***ALL:*** *For some elements, the entire element is placed completely into one condition state as described in the appropriate condition state table (e.g. streams and waterways).*

Condition State tables (See Tables 4.1 – 4.19) have been created for each material type (e.g. steel, concrete) and, where required, for specialized elements (e.g. bearings, expansion joint seals, etc). The Condition State that an element is in is defined by the severity of the defect(s) that exist in that element. All material defects are defined in Part 1, Section 2 of this manual. In general, the severity of a defect is defined by the terms "Light, Medium, Severe and Very Severe". The definitions of these severity terms are also contained in Part 1, Section 2 for each type of defect.

As a general rule of thumb, the following philosophy is used for most condition state tables:

(i) Excellent
- This refers to an element (or part of an element) that is in "new" (as constructed) condition
- No visible deterioration type defects are present and remedial action is not required.
- Minor construction defects do not count as visible deterioration type defects.
- Examples:
    - "bug holes" in concrete barrier walls
    - well-formed patina in atmospheric corrosion resistant(ACR) steel girders

(ii) Good

- This refers to an element (or part of an element) where the first sign of "Light" (minor) defects are visible. This usually occurs after the structure has been in service for a number of years. These types of defects would not normally trigger any remedial action since the overall performance of the element is not affected.
- Examples:
    - Light corrosion (no section loss)
    - Light scaling
    - Narrow cracks in concrete
- Light decay in wood

(iii) Fair

- This refers to an element (or part of an element) where medium defects are visible. These types of defects may trigger a "preventative maintenance" type of remedial action (e.g. sealing, coating, etc) where it is economical to do so.
- Examples:
- Medium corrosion (up to 10% section loss)
- Medium cracks in concrete

(iv) Poor

- This refers to an element (or part of an element) where severe and very severe defects are visible. In concrete, any type of spalling or delamination would be considered "poor" since these defects usually indicate more serious underlying problems in the material (e.g. corroding reinforcing steel). These types of defects would normally trigger rehabilitation or replacement if the extent and location affect the overall performance of that element.
- Examples:
- Severe corrosion (Greater than 10% section loss)
- Spalling, delaminations, etc

For concrete elements, a general progression through the various condition states occurs over time. The difference between The "Excellent" and "Good" condition states is not always obvious from a distance. However, minor defects can be detected upon close visual inspection of elements more than 5 years old (depending on the exposure environment). The following general guidelines may be used by the inspector to supplement visual inspection data to determine when a concrete element should progress from "Excellent" to "Good" (These times can be increased by 50% for Precast elements):

(i) Severe Environment – 5 years to become Good
(ii) Moderate Environment – 15 years to become Good
(iii) Benign Environment – 25 years to become Good

The presence of material defects usually triggers further, more detailed investigations. The most common types of investigations are for concrete elements (e.g. Bridge Deck Condition Survey, Substructure Condition Survey, etc). Investigations can also be done for other materials such as steel, wood, etc. Additional investigations are usually triggered when a pre-determined percentage is exceeded in the "poor" Condition State. Tables 4.1 to 4.19 list these triggers. In some cases, the first sign of a material defect would trigger a more detailed investigation. An example would be a fatigue crack in a steel girder, which would trigger an immediate fatigue investigation. Part 3 of this manual describes some of the additional investigations that can be done.

In addition, material defects often lead to performance deficiencies, which would trigger other follow-up actions, such as a strength evaluation. Performance deficiencies and corresponding follow-up actions are described in Section 5.

MATERIAL CONDITION STATE TABLES

Table 4.1: Asphalt Wearing Surface

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Light cracking	Medium cracking	Severe to very severe cracking
	Light ravelling	Medium ravelling	Severe and very severe ravelling
			All areas with loss of bond
	Light Potholes	Medium Potholes	Severe and very severe potholes
	Light wheel track rutting	Medium wheel track rutting	Severe and very severe wheel track rutting
	Light Rippling	Medium Rippling	Severe and Very Severe Rippling
	Light Flushing	Medium Flushing	Severe and very severe flushing

For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. alligator cracks, radial cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.

Table 4.2: Bearings

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Hairline cracks in elastomeric pads	Narrow to medium cracks in elastomeric pads	Very wide cracks in elastomeric pads and/or steel plates debonded
	Light bulging or shear deformations in elastomeric pads, or light local deformation of roller/rocker plates	Medium bulging or shear deformations in elastomeric pads, or medium local deformation of roller/rocker plates	Severe bulging or shear deformations in elastomeric pads, or severe local deformation of roller/rocker plates
	Light scoring/scratches in TFE or stainless steel	Medium scoring/scratches in TFE or stainless steel	Severe scoring/scratches or rips and tears in TFE or stainless steel
	Light Corrosion	Medium Corrosion	Severe and very severe corrosion and or cracks in steel
	Anchor bolts slightly bent	Anchor bolts severely bent and cracked	Anchor bolts are broken
	Guide bars and thrust plates slightly worn	Guide bars and thrust plates moderately worn	Guide bars and thrust plates severely worn and/or loose or missing nuts
	Up to 5% of bonded sliding surface is debonded	5% to 20% of bonded sliding surface is debonded	Over 20% of bonded sliding surface is debonded
			Internally confined compression material is squeezing or squeezed out

Table 4.3: Coating* – Steel Railings

Excellent Condition	Good Condition	Fair Condition	Poor Condition

RUST CONDITION** RATING CATEGORY 1	RUST CONDITION RATING CATEGORY 2	RUST CONDITION RATING CATEGORY 3	RUST CONDITION RATING CATEGORY 4 or higher

Table 4.4: Coating* - Structural Steel Substructures And Superstructures

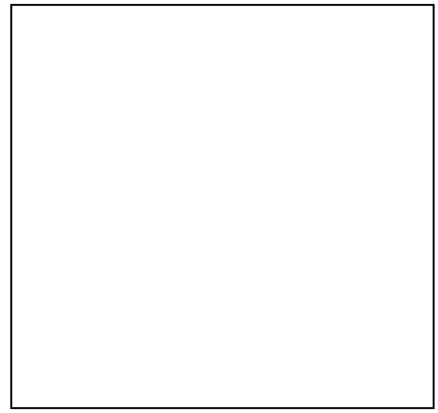
Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Minor checking, cracking, alligatoring, chalking	Checking, cracking, alligatoring	Severe checking, cracking, alligatoring
		Intercoat delamination, peeling (top coat only)	Undercutting, blisters, peeling (prime coat), underfilm corrosion
		Signs of chemical attack	
	Overspray, runs, sags, pinholing	Bridging, edge defects, shadows, pinpoint rusting	
RUST CONDITION** RATING CATEGORY 1	RUST CONDITION** RATING CATEGORY 2	RUST CONDITION** RATING CATEGORY 3	RUST CONDITION** RATING CATEGORY 4 or higher
		Coating Condition Survey is required if the combined area in the Fair and Poor Condition States is greater than 25% and the area in the Poor Condition State is less than 10% ***	

* Galvanized elements are included under the “Coating” category

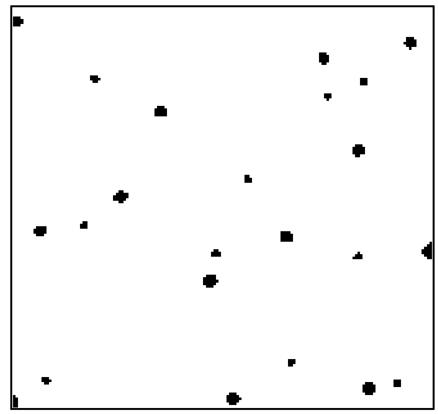
** Rust Condition Ratings based on ASTM D 610 sketches are shown in Figure 4.1.

*** In order to consider overcoating as a viable rehabilitation option, a detailed condition survey should be triggered before deterioration is too widespread. If the percentage in Poor Condition exceeds 10%, overcoating is not a feasible treatment and a coating condition survey is not required.

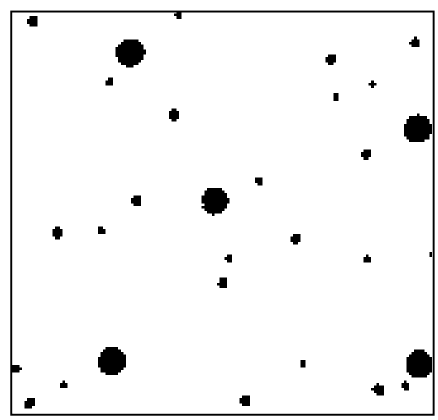
Category 1: **No Rust**
Condition State: **Excellent**



Category 2: **Light Surface Rust**
Condition State: **Good**



Category 3: **Medium Surface Rust**
Condition State: **Fair**



Category 4: **Severe Surface Rust**
Condition State: **Poor**

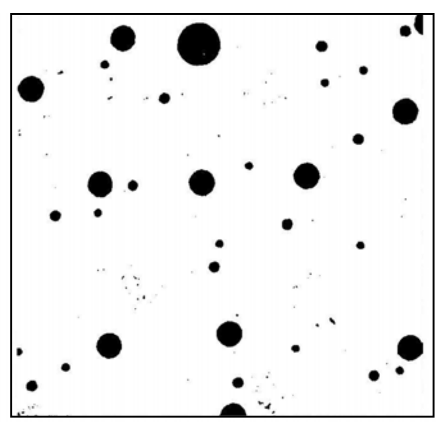


Figure 4.1: Rust Condition Rating Categories for Coatings

Table 4.5: Concrete – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light scaling	Medium scaling	Severe to very severe scaling, erosion and disintegration
	Rust stains on concrete due to corroding rebar chairs	Rust stains on concrete due to corroding reinforcing steel	Medium to very severe corrosion of reinforcing steel
	Surface carbonation (Reaction with CO_2, associated discolouration, shrinkage and cracks)	Surface defects such as stratification, segregation, cold joints, abrasion, wear, slippery surfaces, wet areas and surface deposits (except on soffits).	
	Light honeycombing and pop-outs	Medium honeycombing and pop-outs	Severe to very severe honeycombing and pop-outs
	Hairline and Narrow cracks	Medium cracks	All wide cracks
	Light alkali-aggregate reaction	Medium alkali-aggregate reaction	Severe and very severe alkali-aggregate reaction
		Stable relative displacement between precast units. Leaking between precast units.	Active relative displacement between precast units
			All delaminated and spalled areas
		Active wet areas on soffit without cracks	Active wet areas or leachate deposits on soffit with associated cracks
			Condition Survey if area of deterioration in this state >10% for substructures
			Deck Condition Survey if area of deterioration in this state >5% for superstructures

Notes:

(1) For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. pattern cracks, map cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.
(2) If shear cracks are found at girder ends, an evaluation should be done. If cracks are wide, the inspector should mark "URGENT" for the timeframe of the evaluation.

Table 4.6: Concrete - Top of Deck Beneath Asphalt Wearing Surface

Based on Visual Inspection of Asphalt			
Excellent Condition	**Good Condition**	**Fair Condition**	**Poor Condition**
No Asphalt Defects.	Top-Down Asphalt Defects	Medium Bottom-Up Asphalt Defects	Severe Bottom-Up Asphalt Defects
		Local protrusions in asphalt.	All Potholes in asphalt.
	Light and medium isolated cracks in asphalt.	Wide isolated cracks in asphalt. (Cracks include: longitudinal cracks, above location of voids, edge of beam flanges, joint between precast units, construction joints, etc., or transverse cracks)	All Pattern cracking in asphalt (e.g. map, alligator, radial, edge cracking).
	All Bond Defects (e.g. rippling, loss of bond) in asphalt.		
	All Surface Defects (e.g. ravelling, flushing, slippery surface) in asphalt.		
	All Surface Distortions (wheel track rutting) in asphalt.		
			Condition survey if the area of deterioration in this state >5% if not already done.

Notes:

(1) For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. alligator cracks, radial cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.

(2) If a bridge has been recently repaved without rehabilitating the deck, the inspector must estimate the condition of the concrete deck using other means. This would include using previous inspection information, the age of the waterproofing, deck condition survey data, etc.

Table 4.7: Drainage System

Excellent Condition	**Good Condition**	**Fair Condition**	**Poor Condition**
No observed material defects	**Up to 20% of drainage system has loose or deteriorated components, connections or fasteners**	**20% to 60% of drainage system has loose or deteriorated components, connections or fasteners**	**More than 60% of drainage system has loose or deteriorated components, connections or fasteners** **Broken pipe components resulting in water draining onto substructure**

Table 4.8: Embankments

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Up to 10% loss of material for embankments not directly supporting foundations; or, up to 5% loss for embankments directly supporting foundations	10% - 30% loss of material for embankments not directly supporting foundations; or 5% to 15% loss for embankments directly supporting foundations; or, loss of material to the top of foundations	More than 30% loss of material for embankments not directly supporting foundations; or, more than 15% loss for embankments directly supporting foundations; or, loss of material to the bottom of foundations

Table 4.9: Expansion Joint – Armouring and Retaining Devices

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light Corrosion*	Medium Corrosion*	Severe Corrosion* Bolts, anchors, armouring, clamping devices or welds are loose, broken or missing.

***** As defined in Table 4.16.

Table 4.10: Expansion Joint – Seals/Sealants

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Abrasions in seal with no perforations	Loss of resiliency of seal but no perforations	Cracks, tears or holes in the seal
			Seal has debonded
			Seal is allowing leakage on the substructure. Sealant debonded, pulled out or settled.

Table 4.11: Masonry Construction

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Hairline and narrow cracks	Medium cracks	Wide cracks
		Leaching of lime based mortar	
	Light splitting, spalling and disintegration	Medium splitting, spalling and disintegration	Severe and very severe splitting, spalling and disintegration
	Light loss of pointing mortar	Medium loss of pointing mortar	Severe and very severe loss of pointing mortar and stones

Table 4.12: Signs

Excellent	Good	Fair	Poor
No observed defects	Not a standard sign	Not located according to standards	Illegible
			Gives misleading, wrong or inaccurate information
		Loose, damaged or bent components	Broken or missing components
			Sign is missing

Table 4.13: Slope Protection

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Loss or deterioration of less than 20% of slope protection material	Loss or deterioration of 20% to 60% of slope protection material	Loss or deterioration of more than 60% of slope protection material

Table 4.14: Soil-Steel Structures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Crimping of corrugations covering less than 5% of length	Crimping of corrugations covering 5% to 15% of length	Severe crimping of corrugations covering more than 15% of length
		Hairline to narrow cracks	Medium to wide cracks at fastener locations
	Pin-point rusting over surface	Shallow pitting and corrosion scale over surface	Deep pitting, heavy corrosion scale or several locations of corrosion perforation

Table 4.15: Steel – Atmospheric Corrosion Resistant Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects with smooth uniform rust layer (patina)	Early signs of patina flaking and no section loss	Flaking and delamination of Patina up to 10% section loss	More than 10% section loss
			All cracks
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Evaluation and condition survey* if > 10% in this state.

* Involves measuring thickness of critical members to determine section loss as it varies across the element.

Table 4.16: Steel or Aluminum – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light corrosion – no section loss	Medium corrosion - up to 10% section loss	Severe and very severe corrosion – more than 10% section loss
			All cracks (immediate action is required -estimate repair area)
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Evaluation and condition survey* if > 10% in this state.

* Involves measuring thickness of critical members to determine section loss as it varies across the element.

Table 4.17: Steel or Aluminum - Railings

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light corrosion – no section loss	Medium corrosion - up to 10% section loss	Severe and very severe corrosion – more than 10% section loss
	Slight loss of cable tension or slight slippage of cable anchors and splices	Moderate loss of cable tension or slight slippage of cable anchors and splices	Significant loss of cable tension or slight slippage of cable anchors and splices
			Broken cable strands/supports
			Collision or vandalism damage/missing sections
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies

Table 4.18: Streams and Waterways

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	A few locations of scour or degradation of the stream bed or stream banks but not exposing the foundations	Numerous locations of scour or degradation of the stream bed or stream banks to the top of the previously covered foundations	Scour or degradation of the stream bed or stream banks to the bottom of previously covered foundations
	Slight scour at inlet or outlet of culverts and soil-steel structures	Moderate scour at the inlet or outlet of culverts and soil-steel structures	Extensive scour around the inlet or outlet of culverts and soil-steel structures with loss of embankment fill
	Stream alignment shifted but not encroaching against components previously not subject to stream flow	Stream alignment shifted and encroaching close to components not previously subject to stream flow	Stream alignment shifted with stream flow directly against most of a component not previously subject to stream
	A few locations of aggradation not affecting the stream flow at the structure	Medium aggradation having a significant effect on the stream flow at the structure	Extensive aggradation very severely affecting the stream flow at the structure)

Table 4.19: Wood – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light weathering, checks, splits and shakes	Medium weathering, checks, splits and shakes	Severe and very severe weathering, checks, splits and shakes
	Light rot or decay	Medium rot or decay	Severe and very severe rot or decay
	Light insect damage	Medium Insect Damage	Severe and very severe insect damage
	Light abrasion and wear	Medium Abrasion and wear	Severe and very severe abrasion and wear
	Light cracking, splintering, crushing and shattering	Medium cracking, splintering, crushing and shattering	Severe and very severe cracking, splintering, crushing and shattering
	Light fire and chemical damage	Medium fire and chemical damage	Severe and very severe fire and chemical damage
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Condition survey if area of deterioration in this state > 10%

SECTION 5 – SUSPECTED PERFORMANCE DEFICIENCIES

A Performance deficiency should be recorded if an element's ability to perform its intended function is in question, and one or more performance defects exist. Performance defects for the various elements of a structure are described in Section 2, Part 1 of this manual. Often, an inspector "suspects" a performance deficiency, but is unsure of the extent of this deficiency until some follow-up action is taken. A list of common performance deficiencies is shown in Table 5.1. These deficiencies are often applicable to several elements, however, in some cases, the deficiencies listed are applicable to only one type of element. An example of a suspected performance deficiency is "Load Carrying Capacity". The typical follow-up action for this deficiency would be to carry out a strength evaluation of the structure (or element). Table 5.1 also describes typical deficiencies for various elements, and lists possible follow-up actions. The follow-up action could take the form of either an additional investigation or a maintenance operation.

In most cases, performance defects in an element are closely related to or attributable to material defects. In some cases, performance defects exist due to defects in design or construction and may not be directly related to material defects. Also, performance defects in a component may be the result of unexpected behaviour of the structure or due to performance defects in other components of the structure.

It should be noted that the list of suspected performance deficiencies should be considered during the inspection of each element. If no performance deficiencies are noted, the inspector should indicate that on the form by filling in "0" or "none". It is important to complete the form in this manner to ensure that a conscious decision is made regarding each element's ability to perform its intended function.

Table 5.1: Suspected Performance Deficiencies

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
1	Load Carrying Capacity	Girder, Deck Top, Railing System, etc (Note – deficiencies in most elements can trigger a strength evaluation)	• Material defects leading to loss of strength, or which are indicative of inadequate strength of the component (eg.20% section loss at mid-span of girder) • Detrimental modifications made subsequent to construction;	• Strength evaluation
2	Excessive Deformations	Railing System, Deck Top, Truss Chord, Abutment Wall, Bearings, etc	• Severely bent members • Overloading, either single or repetitive occurrence, resulting in permanent deformations of the deck or deck components. • Permanent deformations, especially in compression components • Unanticipated or excessive vibration or deflection of components, connections or joints under live loads • Unexpected noise from components or connections due to vehicles moving across the structure. • Mis-alignment, lateral deformation, warping, etc. of components; • Inability of the abutment to withstand lateral earth pressures, as indicated by long, medium horizontal cracks in abutments; • Deformation of the roof slab, floor slab or walls of culverts. • Deformation of soil-steel structures such as flattening or peaking of the soffit or buckling of the shoulders or haunches; • Up-lift at ends of soil-steel structures • Movements causing distress in a bearing or it's components, or in other structure components;	• Strength evaluation • Monitoring of deformations (displacements or rotations)
3	Continuing settlement	Foundation	• Loss of strength or support for applied loads due to material defects; • Loss of material supporting foundations due to scour or erosion • Consolidation or failure of underlying soil resulting in cracking or movement of foundations, abutments or piers • Loss of contact between piles and pile cap or pier cap; • Changes in the inclination of piles. • Rotational movement of pile caps and loss of full contact with piles.	• Regular Monitoring of settlement, pier and abutment elevations and crack widths • Strength evaluation • Geotechnical investigation • Underwater investigation
4	Continuing Movements	Abutment Wall, Pier, Deck Top,	• Out of plumb of abutment walls, piles, piers or other components supported on	• Regular monitoring and measurement of

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
		Bearings, etc	them; • Tilting or bulging of Retained Soil System (RSS) walls • Unusual or unexpected substructure movements occurring during the passage of heavy vehicles over the bridge; • Tapering or misalignment of cracks and joints in foundations, abutments, piers or other components supported on them; • Sudden drops or kinks in the structure profile over piers or abutment walls when sighting along railings or beam lines; • Abnormally large or small openings or misalignment of deck expansion joints at abutments and piers; • Abnormal displacements or inclinations of bearings; • Abnormally large or small clearance between ballast wall and superstructure; • Cracks in abutment wall and ballast wall • Shift in alignment from original position;	movements, inclinations, crack widths, etc. • Underwater investigation • Geotechnical investigation
5	Seized Bearings	Bearings	• Binding or jamming of expansion or rotational components due to corrosion, lack of lubrication or damage to sliding surfaces;	• Strength evaluation to account for change in articulation • Lubricate Bearings (Maintenance Operation)
6	Bearing not uniformly loaded/unstable	Elastomeric Bearing, Rocker Bearing, etc	• Non-uniform contact of bearing surfaces with each other or with bearing seat • Excessive inclinations of bearings	• Regular monitoring of bearing movements
7	Jammed expansion Joint	Armouring/ retaining devices	• Inadequate joint gap to accommodate anticipated further movement; • Surfacing materials have jammed in the joints during resurfacing of deck; • Design or construction problems not allowing proper movement of multi-seal joints.	• Regular monitoring of deck movements • Clean out gap (Maintenance operation)
8	Pedestrian/ vehicular hazard	Armouring/ retaining devices, Sidewalk	• Vertical or horizontal misalignment across the joint; • Severe material defects (e.g. Spalling) • Horizontal, vertical or rotational displacements in curbs and sidewalks as they are hazardous to pedestrian and vehicular safety, and present obstructions to snow plows. • Inadequate curb height, or loss of curb height for sidewalks due to the placement of an additional layer of wearing surface or deck overlay	• Remove obstruction (Maintenance operation) • Review Code requirements for curb height
9	Rough Riding Surface	Wearing Surface, Approach slabs	• Rough approaches, settlement or consolidation of approach embankments, or deterioration of the approach slabs or	• Smooth out asphalt at approach (Maintenance operation)

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
			ramps, resulting in vehicles "bouncing" onto the bridge. In addition to applying excessive dynamic loading to the bridge, this may also result in difficulty in maintaining vehicle control • Depressions and cracks in the roadway pavement above culverts and soil-steel structures;	• Strength evaluation
10	Surface Ponding	Sidewalk, Wearing surface	• Water ponding on sidewalks/wearing surface, as it presents a safety hazard, especially if allowed to freeze;	• Fill in depression with asphalt (Maintenance Operation)
11	Deck Drainage	Drainage System	• Deck drains not provided where necessary, or have inadequate size of opening; • Deck drains and drainage systems improperly constructed with inadequate slopes or sharp directional changes; • Drainage system plugged or partially plugged and not allowing for free and unobstructed flow of water; • Drainage outlets discharging directly onto structure components or roadways below the deck; • Drainage outlets discharging directly onto embankment without proper provision for collecting, channelling and controlling of discharge with splashpads, spillways or gutters; • Inadequate provision for drainage at the structure approaches.	• Review deck drainage requirements
12	Slippery Surfaces	Deck Top	• Loss in riding comfort and potential loss of vehicle control due to defects in the component material; • Loss of protection to underlying surfaces due to defects in the wearing surface materials;	• Resurface problem area (Maintenance Operation)
13	Flooding/ Channel Blockage	Streams & Waterways	• **The inspector should look for the following evidence of high water levels, inadequate opening at the structure and adverse affects on other components of the structure:** • Bending or buckling of the lower chord of steel trusses in the downstream direction by ice or heavy debris; • Ice scars and damage to substructures; • Coarse debris, such as branches and small trees, caught or wedged under the superstructure; • Fine debris, such as grass and twigs, on fences, trees, embankments, structures, etc.; • Wash lines on bare soil slopes;	• Determine historical frequency of flooding and recorded water levels and compare to current high water elevation • Monitor water elevations throughout year • Perform hydrology study

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
			• Mud or silt deposited on embankments; • Marks and stains on structures.	
14	Undermining of Foundation	Streams & Waterways or Foundation	• Loss of material supporting foundations due to scour or erosion.	Underwater Investigation
15	Unstable Embankments	Embankments	• Settlement of embankment, slope protections or approach roadway; • Sliding failure of the toe or slopes of the embankment; • Surface or deep seated slips; • Loss of embankment material from under foundations.	Geotechnical investigation
16	Other			

SECTION 6 – MAINTENANCE NEEDS

Maintenance work is defined as any type of work that does not require the issuing of a capital construction project. Routine maintenance is an important part of prolonging bridge life. It is usually carried out by bridge crews or road maintenance personnel and involves both preventative maintenance and minor repair work. The bridge inspector should note the need for maintenance work when performing a detailed visual inspection. This list is then forwarded to maintenance crews for action. At the completion of the maintenance work, the maintenance crew should inform the engineer responsible for the detailed inspection so that records can be updated. A standard list of maintenance needs, and a description of each, is shown in Table 6.1.

Table 6.1: Maintenance Needs

	Maintenance Need	**Description**
1	Lift and Swing Bridge Maintenance	The operation, maintenance and repair activities that are unique to lift and swing bridge structures, including all mechanical equipment and electrical devices such as signals, flashers, lighting, navigation lights, etc., but <u>not</u> including work defined by other structural maintenance operations.
2	Bridge Cleaning	The cleaning of bridge components including: 1) Washing of bearings, bearing seats, truss members, etc. 2) Sweeping of bridge decks, curbs and gutters. 3) Removal of debris from expansion joints. 4) Debris pick-up or minor removal of aggregate. 5) Cleaning of catch-basins, man-holes and deck drains.
3	Bridge Handrail Maintenance	The painting, repair and/or replacement of metal handrails and posts, as well as touch-up painting activities.
4	Painting Steel Bridge Structures	The preparation (sandblasting, etc.) and painting of structural steel. Includes handrails when performed as part of an overall bridge painting operation.
5	Bridge Deck Joint Repair	The repair and/or replacement of expansion and/or fixed deck joints and end dams.
6	Bridge Bearing Maintenance	The adjustment, repair and/or replacement of bridge bearings. Includes all work directly associated with bridge bearings.
7	Repair to Structural Steel	The repair of all structural steel, including repair or replacement of steel components, bolts and fasteners.
8	Repair of Bridge Concrete	The repair of all concrete components of the structure, such as decks, curbs, pedestrian walks, concrete handrail posts, parapet walls, abutments and piers, except when the repair is more directly associated with one of the other defined bridge maintenance operations.
9	Repair of Bridge Timber	The repair of all bridge timber, including the repair of timber decks on steel bridges.
10	Bailey Bridges – Installation, Maintenance and Removal	The installation, removal, repair and maintenance work that is unique to Bailey Bridges, but <u>not</u> including work defined by other structural maintenance operations.
11	Animal/Pest Control	The installation and maintenance of animal/pest control devices under bridge structures such as pigeon-proofing.
12	Bridge Surface Repair	The repair of bridge surfaces such as pothole patching.
13	Erosion Control at Bridges	Operations performed to prevent or repair damage due to erosion, such as scour at abutments and around piers, and washouts on slopes. Includes removal of obstructions to water flow, clearing of vegetation growth, etc.
14	Concrete Sealing	The sealing or treatment of bridge concrete surfaces with approved materials, as well as the preparation of surfaces prior to treatment.
15	Rout and Seal – Concrete and Asphalt Pavement on Bridge Decks	The routing of joints and/or cracks in concrete and asphalt pavement and the filling of same with joint fillers or rubberized asphaltic sealing compounds.
16	Bridge Deck Drainage	The repair, maintenance and replacement/ extension of deck drains. Includes steaming and calcium application to unthaw.

SECTION 7 - INSPECTION FORMS

The inspection forms required for recording field information are shown at the end of this Section. The form usually consists of four main pages. A description of each page and the definitions of the various data entry fields are contained below.

INVENTORY DATA AND HISTORICAL DATA (PAGE 1)

This is a one page summary of general inventory data and historical inspection/rehabilitation information. It is often useful for the inspector to take this page to the field for reference purposes. The type of data on this page is defined by the owner and usually originates from a main inventory database. The inspector should note any discrepancies in the data when performing the inspection. An example of a typical form is shown at the end of this section.

SCHEDULED IMPROVEMENTS AND APPRAISAL INDICES (PAGE 2)

In some jurisdictions, it is often of benefit to the inspector to know what improvements are planned for the bridge. In addition, if some specific studies have been done (e.g. seismic, fatigue, etc.), a summary of the results may be useful to the inspector in the field (e.g. The inspector may pay particular attention to certain details if they have been identified as susceptible in a study). Examples of some of this optional appraisal data are shown at the end of this section.

FIELD INSPECTION INFORMATION AND ADDITIONAL INVESTIGATIONS (PAGE 3)

FIELD INSPECTION INFORMATION

This page is completed in the field and consists of the following data fields:

Date of Inspection: The date when the inspection was done.
Inspector: The name of the inspector and the name of the consulting engineering company (if applicable).
Others in Party: The other member(s) of the inspection team.
Equipment Used: List of any special equipment used in the inspection.
Weather: Indicate the weather conditions at the time of the inspection.
Temperature: Indicate the temperature at the time of the inspection.

ADDITIONAL INVESTIGATIONS REQUIRED

These investigations are described in Part 3 of this manual. The priority (urgency) of the inspection is described below:

Priority – None: Indicates that the investigation is not required.
Priority – Normal: Indicates that the investigation should be completed before the time of the next inspection (usually within two years).
Priority – Urgent: Indicates that the investigation should be completed as soon as possible.
Special Notes: Indicate any general comments about the bridge in this area.
Next Detailed Visual Inspection: Indicate the date when the next biennial inspection is required. If deemed necessary by the inspector, this could be at a time sooner than two years.

ELEMENT DATA (PAGE 4)

The data for each bridge element shall be shown on one table. The tables can be duplicated for as many elements as exist for each bridge.

Element Group: The main category of element (See Table 2.1)
Element Name: The individual element name and sub-element name (if applicable) (See Table 2.1)
Location: A description of where the element is on the structure (e.g. East pier, portal bracing, etc)
Material: The material the element is made of (See Table 7.1)
Element Type: The specific type of element (e.g. I-girder, elastomeric bearing, etc.)
Protection System: The type of protection system for that element (e.g. Deck overlay type – latex, cathodic protection; rebar type- coated, stainless, etc.)

Environment: The degree to which the element is exposed to salt spray.
Benign - Not exposed, e.g. River Pier
Moderate – Exposed, but element protected, e.g. Asphalt covered and waterproofed deck
Severe – Exposed, and element not protected, e.g. Exposed concrete deck, Barrier Wall

Length, Width, Height: The dimensions used to calculate the total quantity of the element as described in Table 3.1
Count: The number of occurrences of the element under consideration (e.g. 6 girders)
Total Quantity: The count times the quantity for one element (Units are defined in Table 2.1)

CONDITION DATA

This table is used to record the "severity and extent" of the material defects of the various bridge components as described in Section 4. A close-up visual inspection is required for all elements. Appropriate special equipment (Bridgemaster, bucket truck, ladders, etc) should be used to facilitate this assessment**.**

When recording the "extent" (quantity) that an element is in a particular condition state, the following guidelines should be followed:

- Select the appropriate inspection quantity units from Table 2.1 (m^2, m., Each, All)
- For Elements with units of m^2 or m:
- The actual inspection quantity units should <u>always</u> be used for the part of the element in the Poor Condition State (e.g. 15 m^2). Percent should <u>not</u> be used unless the quantity in poor exceeds 50%.
- Enter the estimated quantity in the 3 Condition States (Good, Fair, Poor). See the appropriate Condition State Table in the Section 4.
- Quantity in Excellent = Total - Quantities in other states
- Elements with "each" as unit - give number of occurrences of the element in each State
- Elements with "all" as unit - place entire quantity in one state
- If an element is not completely visible, or the view is obstructed, quantities should be estimated and the "Limited Inspection" box should be checked on the form.

SUSPECTED PERFORMANCE DEFICIENCIES

Suspected Performance Deficiencies, as described in Section 5, should be recorded if a follow-up action is required. (e.g. strength evaluation, specialized inspection, etc.) Select deficiencies from pick list on page 3 of the form and enter the appropriate Code number. If no suspected performance deficiencies exist, enter "none" or "0".

MAINTENANCE NEEDS

Maintenance Needs, as described in Section 6, should be selected from the pick list on page 3 of the form and the appropriate Code number entered on the form.

COMMENTS

- Comments should provide information on the poor condition state (e.g. How the quantity was estimated, location of defects, etc.).
- Comments can also be used to provide general information on the element.

RECOMMENDED WORK

This area should be used by the inspector to recommend rehabilitation work and the time frame for completing the work. It is used when element condition is such that placing the bridge on the rehabilitation program is warranted. For example, defects such as spalled concrete on an abutment wall, would not warrant that the bridge be placed on the rehabilitation program just to repair the wall. **Recommended work must be consistent with the condition of the element**, and as such, is usually driven by the quantity of defects in the fair and poor condition states. In some cases, defect quantities are small, but the element is critical, and the inspector may recommend that the bridge be placed on the rehabilitation program within a specific timeframe. **It should be noted that recommended work is for rehabilitation type work only and not intended for maintenance work, functional deficiencies or additional investigations.** These types of recommendations are covered in other parts of the inspection form.

If the inspector is unsure of the extent of the work required based on the visual inspection (e.g. patch, waterproof & pave versus overlay), the following general terms should be used: **Major rehabilitation or Minor rehabilitation**.

Priority**:**

Urgent: An unexpected repair or rehabilitation that is required immediately. The design is to be done immediately and construction should also be in the current construction year. (e.g. fatigue crack in steel girder). Usually carried out using Preservation Management funding.

Now (<1 year): A rehabilitation that is required with some degree of urgency, but can still be can completed in a reasonable time frame. (Also known as “Now” need). The design phase should be started within a few months, with construction being completed by the end of the next construction year.

1 to 5 years: A rehabilitation that can be done in a normal time frame. The rehabilitation is to be designed and preferably completed in one to five years.

6 to 10 years: Some rehabilitation work is expected in 6 to 10 years.

None: No work is expected in the next 10 years.

Table 7.1: List of Materials

MATERIAL			
Aluminum	Corrugated steel	Mass concrete	Steel
Asphalt	Gravel	Plastic	Weathering steel
Cast Iron	Hybrid	Precast concrete	Wood
Cast-in-place concrete	Masonry	Retained soil system	Other

Ontario Structure Inspection Manual – Inspection Form **MTO Site Number:**

Inventory Data:			
Structure Name			
Main Hwy/Road #	On ☐ Under ☐	Crossing Type:	Navig. Water ☐ Non-Navig. Water ☐ Rail ☐ Road ☐ Ped. ☐ Other ☐
Hwy/Road Name			
Structure Location			
Latitude		Longitude	
Owner(s)		Heritage Designation:	Not Cons. ☐ Cons./not App. ☐ List/not Desig. ☐ Desig./not List ☐ Desig. & List ☐
MTO Region		Road Class:	Freeway ☐ Arterial ☐ Collector ☐ Local ☐
MTO District		Posted Speed	No. of Lanes
Old County		AADT	% Trucks
Geographic Twp.		Inspection Route Sequence	
Structure Type		Interchange Number	
Total Deck Length	(m)	Interchange Structure Number	
Overall Str. Width	(m)	Min. Vertical Clearance	(m)
Total Deck Area	(sq.m)	Special Routes:	Transit ☐ Truck ☐ School ☐ Bicycle ☐
Roadway Width	(m)	Detour Length Around Bridge	(km)
Skew Angle	(Degrees)	Direction of Structure	
No. of Spans		Fill on Structure	(m)
Span Lengths			(m)

Historical Data:			
Year Built		Last Evaluation	
Last Biennial Inspection		Current Load Limit	/ / (tonnes)
Last BridgeMaster Inspection		Load Limit By-Law #	
Last Condition Survey		By-Law Expiry Date	
Last Underwater Inspection			

Rehab History: (Date/description)

Page 1

Scheduled Improvements:			
Regional Priority Number		Programmed Work Year	
Nature of Program Work:			

Appraisal Indices:		**Comments**
Fatigue		
Seismic		
Scour		
Flood		
Geometrics		
Barrier		
Curb		
Load Capacity		

Field Inspection Information:	
Date of Inspection:	
Inspector:	
Others in Party:	
Equipment Used:	
Weather:	
Temperature:	

Additional Investigations Required:	Priority		
	None	Normal	Urgent
Detailed Deck Condition Survey:			
Non-destructive Delamination Survey of Asphalt-Covered Deck:			
Substructure Condition Survey:			
Detailed Coating Condition Survey:			
Underwater Investigation:			
Fatigue Investigation:			
Seismic Investigation:			
Structure Evaluation:			
Monitoring of Deformations, Settlements and Movements:			
Special Notes:			
Next Detailed Visual Inspection:			

Suspected Performance Deficiencies

00 None
01 Load carrying capacity
02 Excessive deformations (deflections & rotations)
03 Continuing settlement
04 Continuing movements
05 Seized bearings
06 Bearing not uniformly loaded/unstable
07 Jammed expansion joint
08 Pedestrian/vehicular hazard
09 Rough riding surface
10 Surface ponding
11 Deck drainage
12 Slippery surfaces
13 Flooding/channel blockage
14 Undermining of foundation
15 Unstable embankments
16 Other

Maintenance Needs

01 Lift and Swing Bridge Maintenance
02 Bridge Cleaning
03 Bridge Handrail Maintenance
04 Painting Steel Bridge Structures
05 Bridge Deck Joint Repair
06 Bridge Bearing Maintenance
07 Repair to Structural Steel
08 Repair of Bridge Concrete
09 Repair of Bridge Timber
10 Bailey bridges - Maintenance
11 Animal/Pest Control
12 Bridge Surface Repair
13 Erosion Control at Bridges
14 Concrete Sealing
15 Rout and Seal
16 Bridge Deck Drainage
17 Other

Element Group:		Length:					
Element Name:		Width:					
Location:		Height:					
Material:		Count:					
Element Type:		Total Quantity:					
Environment:	Benign / Moderate / Severe	Limited Inspection ☐					
Protection System:						Perform. Deficiencies	Maint. Needs
Condition Data:	Units	Exc.	Good	Fair	Poor*		
	m^2 / m / each / % / all						

Comments:

Recommended Work: None ☐ 6 –10 years ☐ 1 – 5 years ☐ < 1 year ☐ Urgent ☐

Element Group:		Length:					
Element Name:		Width:					
Location:		Height:					
Material:		Count:					
Element Type:		Total Quantity:					
Environment:	Benign / Moderate / Severe	Limited Inspection ☐					
Protection System:						Perform. Deficiencies	Maint. Needs
Condition Data:	Units	Exc.	Good	Fair	Poor*		
	m^2 / m / each / % / all						

Comments:

Recommended Work: None ☐ 6 –10 years ☐ 1 – 5 years ☐ < 1 year ☐ Urgent ☐

Element Group:		Length:					
Element Name:		Width:					
Location:		Height:					
Material:		Count:					
Element Type:		Total Quantity:					
Environment:	Benign / Moderate / Severe	Limited Inspection ☐					
Protection System:						Perform. Deficiencies	Maint. Needs
Condition Data:	Units	Exc.	Good	Fair	Poor*		
	m^2 / m / each / % / all						

Comments:

Recommended Work: None ☐ 6 –10 years ☐ 1 – 5 years ☐ < 1 year ☐ Urgent ☐

* A quantity must be estimated using the appropriate unit (e.g. m^2). Percent should not be used.

SECTION 8 – EXAMPLES

The following pages depict examples of various material defects and performance deficiencies. The photographs are listed in order of Element Group first and then by Element. For each photograph, the Condition State is identified for the portion on the element with the worst material defects. During an actual inspection, the quantity of the element in each condition state would be recorded.

Contents Page

8.1 - ABUTMENTS

Figure 8.1(a) Concrete Abutment Wall

Condition State: Fair/Poor

- Numerous medium cracks and several wide cracks with penetration of water through wall and efflorescence.

Performance Deficiency: Load Carrying Capacity

- Deterioration present may reduce the strength of the wall. An evaluation is required to determine the extent of strength reduction.

Figure 8.1(b) Wood Lagging - Abutment Wall

Condition State: Good

- Light weathering of wood.

Performance Deficiency: None

- Slight movement of piles and lagging which has stabilized. No significant effect on other components.

Figure 8.1(c) Wood Crib - Abutment Wall

Condition State: Poor

- Very severe decay, crushing and splintering of wood.

Performance Deficiency: Continuing Movement; Continuing Settlement

- Continuing increasing movement and a loss of strength affecting the stability of the structure.

Figure 8.1(d) Masonry Abutment Wall

Condition State: Fair

- Medium loss of Mortar.

Performance Deficiency: None

- Wall is satisfactorily supporting superstructure loads.

Figure 8.1(e) Concrete Abutment Wall

Condition State: Fair

- Medium cracking under the bearing seat.

Performance Deficiency: None

- No loss of bearing area.

Figure 8.1(f) Concrete Abutment Wall

Condition State: Poor

- Very severe disintegration of concrete.

Performance Deficiency: Bearing Not Uniformly Loaded/Unstable

- Bearing seat area reduced.

Figure 8.1(g) Concrete Ballast Walls

Condition State: Good

- Light surface scaling.

- **Performance Deficiency: None**
  No performance defects.

Figure 8.1(h) Concrete Ballast Wall

Condition Statement: Poor

- Very severe delamination, spalling and corrosion of exposed reinforcement.

Performance Deficiency: Continuing Movement / Load Carrying Capacity

- Continuing movement. Loss of section may affect the capacity of wall to retain backfill. An evaluation is required to determine the extent of strength reduction.

Figure 8.1(i)   Steel Plate Sliding Bearing

Condition State: Good

- Light rusting.

Performance Deficiency: None

- Anchor bolts near end of travel in slots of base plate. Minor allowance for further expansion of superstructure.

Maintenance Needs: Bridge Bearing Maintenance

- Cleaning of debris around bearing required.

Figure 8.1(j)   TFE Elastomeric Bearing

Condition State: Fair/Poor

- Anchor bolts severely bent. Elastomer being squeezed out.

Performance Deficiency: Continuing Movement

- Movement of structure not adequately restrained.

Figure 8.1(k)   Laminated Elastomeric Bearing

Condition State: Fair

- Medium bulging and cracks in elastomeric pad.

Performance Deficiency: None

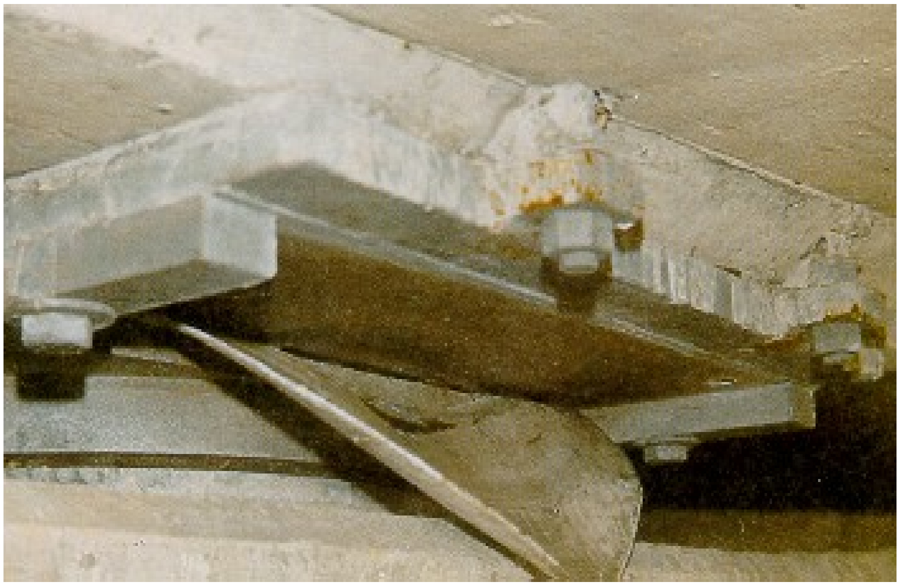


Figure 8.1(l)   Pot Bearing

Condition State: Poor

- TFE squeezed out.

Performance Deficiency: Seized Bearings

- Almost complete loss of sliding capability.

Figure 8.1(m) Steel Rocker Bearing

Condition State: Good

- Light corrosion.

Performance Deficiency: Bearing Not Uniformly Loaded/Unstable

- Rocker should be tilting toward the ballast wall based upon temperature of 20° C at the time of inspection. Rocker in danger of falling over during colder weather.

Figure 8.1(n) Steel Rocker Bearing

Condition State: Excellent

- No material defects.

Performance Deficiency: Bearing Not Uniformly Loaded/Unstable

- Bearing in danger of collapse.

Figure 8.1(o) Roller Bearing

Condition State: Poor

- Very severe corrosion.

Performance Deficiency: Seized Bearings

- Rollers frozen. No capability for movement.

Figure 8.1(p) Concrete Wingwall

Condition State: Good

- Narrow cracking with efflorescence.

Performance Deficiency: None

- No evidence of movement. Wall is satisfactorily retaining backfill.

Figure 8.1(q) Concrete Wingwall

Condition State: Poor

- Very severe erosion, spalling and delaminations.

Performance Deficiency: Continuing Movement / Load Carrying Capacity

- Very severe section loss and continuing movement critically affecting the strength and stability of the wall. An evaluation is required to determine the extent of strength reduction.

8.2 - APPROACHES

Figure 8.2(a) Concrete Approach Slab

Condition State: Excellent

- No visible defects.

Performance Deficiency: Pedestrian/Vehicular Hazard / Rough Riding Surface

- Approach has settled by 20 mm adjacent to the bridge, and provides a rough transition onto the bridge.

Figure 8.2(b) Concrete Sidewalk

Condition State: Poor

- Very severe spalling.

Performance Deficiency: Pedestrian/Vehicular Hazard

- Curb inadequate to prevent vehicles from climbing curb.


Figure 8.2(c) Wood Curb

Condition State: Good

- Insignificant collision damage and deterioration of wood.

Performance Deficiency: None

- Satisfactory curb height, with no displacements or projections.


Figure 8.2(d) Concrete Sidewalk

Condition State: Poor

- Severe scaling and spalling with exposure of severely corroded reinforcement.

Performance Deficiency: Pedestrian/Vehicular Hazard

- Sidewalk surface irregular with large spalls and very severe scaling presenting difficulty for pedestrian passage.

Figure 8.2(e) Wood Sidewalk

Condition State: Good

- Light weathering of wood planks.

Performance Deficiency: Slippery Surfaces

- Slightly slippery surface when wet.

Figure 8.2(f) Gravel Approach

Condition State: Not Applicable

Performance Deficiency: Rough Riding Surface

- Approaches are slightly rough and should be re-graded.

Maintenance Needs: Bridge Surface Repair

Gravel should be removed from the deck surface.

8.3 - BARRIERS

Figure 8.3(a)   Parapet Wall

Parapet Wall

Condition State: Good

- Light defects.

Performance Deficiency: None

- No performance defects.

Hand Railing

Condition State: Poor

- Permanent deformation of hand railing.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

Figure 8.3(b)   Barrier Wall

Condition State: Good

- Light scaling.

Performance Deficiency: None

- No performance defects.


Figure 8.3(c) Concrete Railing

Condition State: Poor

- Many broken rails and posts.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.


Figure 8.3(d) Concrete Railing

Condition State: Poor

- Very severe disintegration of concrete.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

Figure 8.3(e) Steel Railing with Steel Posts (concrete filled)

Condition State (for posts): Poor

- Cracks in posts.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

Figure 8.3(f) Steel Railing with Concrete Posts

Condition State: Poor

- Many broken areas.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

Figure 8.3(g) Concrete Guide Rail

Condition State: Poor

- Very severe disintegration of concrete.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

Figure 8.3(h) Steel Flex Beams

Condition State: Poor

- Permanent deformation of flex beam.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of strength reduction.

8.4 - BEAMS/Main Longitudinal Elements

Figure 8.4(a)   Floor Beam of Steel Through Truss

Condition State: Poor

- Very severe corrosion with perforation of floor beam web.

Performance Deficiency:

- More than 20% loss of cross-section of floor beam. An evaluation is required to determine the extent of strength reduction.

Figure 8.4(b)   Reinforced Concrete Girders

Condition State: Poor

- A few wide longitudinal cracks due to corrosion of reinforcement.

Performance Deficiency: None

- Cracking has little effect on girder capacity.

Figure 8.4(c) Concrete T-Beam

Condition State: Fair

- Full height, medium shear crack.

Performance Deficiency: Load Carrying Capacity

- Potentially inadequate beam capacity. An evaluation is required to determine the extent of strength reduction.

Figure 8.4(d) Steel Beam

Condition State: Poor

- Very severe corrosion of web and bottom flange.

Performance Deficiency: Load Carrying Capacity

- Possible loss of load carrying capacity. An evaluation is required to determine the extent of strength reduction.

8.5 - BRACING

Figure 8.5(a) Sway Bracing and Bottom Lateral Bracing

Condition State: Good

- Light corrosion of both bracing systems.

Performance Deficiency: None

- Bracings are providing satisfactory lateral support.

Figure 8.5(b) Bottom Lateral Bracing

Condition State: Good

- Light corrosion over the surfaces of bracing angles.

Performance Deficiency: None

- Bracing is providing satisfactory lateral support.

Figure 8.5(c) Top Lateral Bracing in Steel Through Truss

Condition State: Poor

- Permanent deformation of member.

Performance Deficiency: Load Carrying Capacity

- Possible loss of strength and ability to provide lateral support, due to deformation. An evaluation is required to determine the extent of strength reduction.

8.6 - COATINGS

Figure 8.6(a) Through Truss - Connection of Primary Components

Condition State: Excellent

- No defects in coating material.

Performance Deficiency: Not Applicable

Figure 8.6(b) Railing

Condition State: Poor

- Material defects and severe surface rust (Rust Condition Rating – Category 4).

Performance Deficiency: Not Applicable

Figure 8.6(c) Connection of Primary Components

Condition State: Poor

- Coating is peeling.

Performance Deficiency: Not Applicable

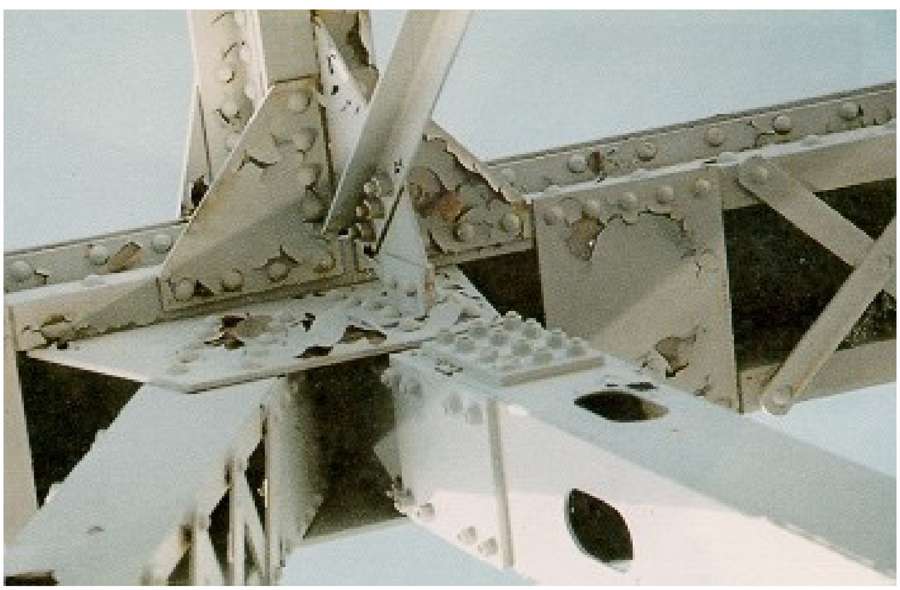


Figure 8.6(d) Through Truss - Connection of Primary Components

Condition State: Poor

- Coating is peeling.

Performance Deficiency: Not Applicable

Figure 8.6(e) Steel Pony Truss

Condition State: Fair

- Material defects and medium surface rust (Rust Condition Rating - Category 3).

Performance Deficiency: Not Applicable

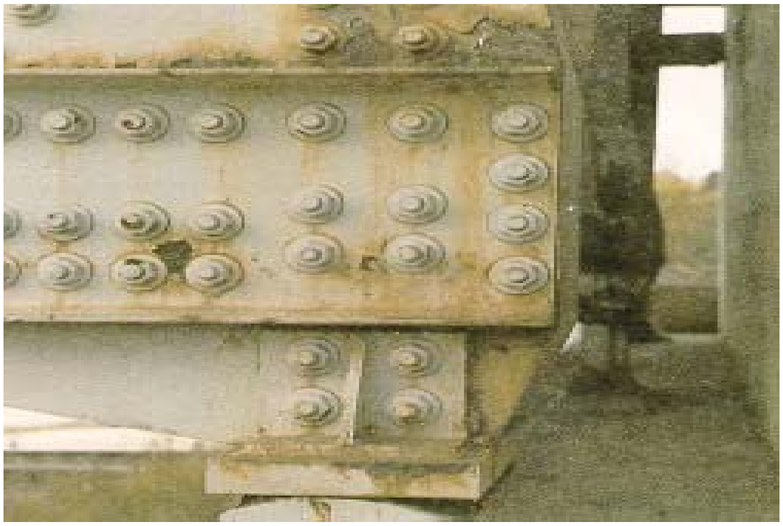


Figure 8.6(f) Truss Primary Connection at Abutment Bearing

Condition State: Poor

- Material defects and severe surface rust (Rust Condition Rating - Category 4) of the connection surface.

Performance Deficiency: Not Applicable

SECTION 8.7 - CULVERTS

Figure 8.7(a)   Multi-plate Pipe Arch

Condition State: Poor

- Severe crimping of corrugations.

Performance Deficiency: Load Carrying Capacity

- Possible inadequate capacity to support applied loading.

Figure 8.7(b)   Multi-plate Pipe Arch

Condition State: Poor

- Wide cracks along bolt line in the valley corrugations of the haunch lap joint.

Performance Deficiency: Excessive Deformations

- Severe local deformation has occurred. Present strength is just adequate, but local or general collapse of the pipe may occur suddenly.

Figure 8.7(c) Wood Culvert

Condition State: Poor

- Walls breaking up and soil entering into the waterway. Washout of fill behind the walls.

Performance Deficiency: Continuing Movement

- Severe sway and continuing movement of the walls with possible sudden collapse.

Figure 8.7(d) Concrete Open Footing Culvert

Condition State: Good

- Light deterioration of concrete.

Performance Deficiency: None

- Culvert supporting fill satisfactorily.

Maintenance Needs: Erosion Control at Bridges

- Heavy vegetation growth should be cleared.

8.8 - DECKS

Figure 8.8(a) Exposed Concrete Deck of a Voided Slab

Condition State: Fair

- Medium longitudinal cracks in deck top surface at the void locations.

Performance Deficiency: None

- Material defects unlikely to cause reduction in load carrying capacity.

Figure 8.8(b) Exposed Concrete Deck

Condition State: Fair

- Medium transverse cracks in deck top surface.

Performance Deficiency: None

- Cracking has no significant effect on the load capacity or load distribution of the deck.

Figure 8.8(c)   Concrete Deck

Condition State: Fair

- Many locations of medium scaling and surface staining due to corrosion of reinforcement.

Performance Deficiency: Rough Riding Surface

- Deck is satisfactorily carrying load but provides a slightly rough ride around the deck joint.

Figure 8.8(d)   Concrete Deck

Condition State: Poor

- Previously repaired delaminated areas are delaminating again.

Performance Deficiency: Rough Riding Surface

- Deck provides a slightly rough ride.

Figure 8.8(e)   Deck Drain (Hole in Deck)

Condition State: Fair

- Medium deterioration, with a full depth wide crack, honeycombing and scaling of concrete at the drain location.

Performance Deficiency: Deck Drainage

- A proper drain has not been installed. Discharge runs along soffit and onto structure components below.

Figure 8.8(f)   Steel Deck Drain

Condition State: Fair

- Medium corrosion over 25% of drainage system.

Performance Deficiency: None

- Drain flows freely and discharges well away from other components.

Figure 8.8(g)   Deck Drain With Basin

Condition State: Good

- Light corrosion of basin.

Performance Deficiency: Surface Ponding

Slight accumulation of debris in the basin, and evidence of slight ponding of water around the basin.

Maintenance Needs: Bridge Cleaning

- Debris should be removed from catch basin.

Figure 8.8(h)   Drainage System

Condition State: Fair

- Insignificant and localized deterioration of drainage trough under deck joint.

Performance Deficiency: None

- Slight accumulation of debris in the trough, not affecting the adequacy of the system.

Figure 8.8(i) Drainage System

Condition State: Good

- Light corrosion of corrugated pipe deck drain. Drainage system on abutment in good condition.

Performance Deficiency: None

Maintenance Needs:

- Pipe drain discharges directly onto embankment causing severe erosion.

Figure 8.8(j) Drainage System

Condition State: Poor

- Drain pipe broken off at connection.

Performance Deficiency: Deck Drainage

Maintenance Needs: Bridge Deck Drainage / Erosion Control at Bridges

- Drain discharging directly onto embankment causing very severe erosion.

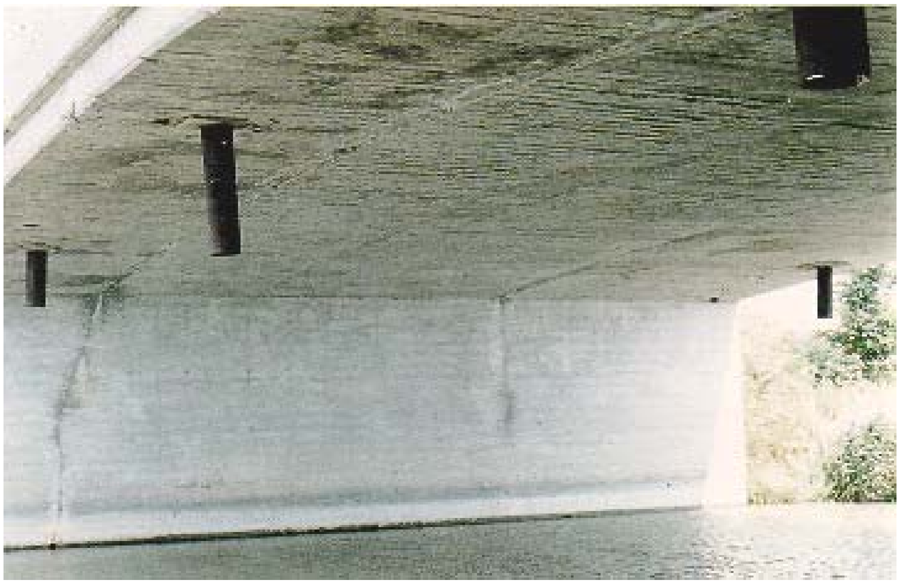


Figure 8.8(k)   Rigid Frame, Thick Slab Soffit

Condition State: Fair

- Medium longitudinal cracks with water leakage and deposits on soffit.

Performance Deficiency: None

- No loss of load carrying capacity.

Figure 8.8(l)   Thick Slab Soffit

Condition State: Poor

- Very severe pattern cracking with severe spalling and exposed corroded reinforcement.

Performance Deficiency: Load Carrying Capacity

- Material defects may result in marginal loss of load carrying capacity. An evaluation is required to determine the extent of strength reduction.

Figure 8.8(m) Soffit of a Thin Slab

Condition State: Fair to Poor

- Medium to wide cracks with local delamination and spalling of concrete over the top flanges of the floor beams and stringers.

Performance Deficiency: Load Carrying Capacity

- Material defects which may affect deck performance locally. An evaluation is required to determine the extent of strength reduction.

Figure 8.8(n) Asphalt Wearing Surface on Laminated Wood Deck

Condition State: Poor

- Very severe breaking up of the wearing surface with very severe deterioration of the deck laminates in many places.

Performance Deficiency: Load Carrying Capacity / Pedestrian/Vehicular Hazard

- Some areas of deck may not support truck wheel loads. An evaluation is required to determine the extent of strength reduction.
- Wearing surface is irregular, resulting in moderate difficulty in maintaining vehicle control.

8.9 - EMBANKMENTS & STREAMS

Figure 8.9(a) Embankments

Condition State: Poor

- Many very deep, closely spaced gullies. Loss of embankment material to top of footing.

Performance Deficiency: None

- Minor movement has stopped. Embankment is essentially stable.

Figure 8.9(b) Embankments

Condition State: Poor

- Loss of 30% to 40% of material due to scour at the toe of slope.

Performance Deficiency: Unstable Embankments

- Embankment is unstable. Progressive failure of slope will continue.

Figure 8.9(c) Embankments

Right Embankment

Condition State: Poor

- Scour of 30% to 40% of embankment.

Performance Deficiency: Unstable Embankment

- Embankment is unstable. Progressive failure will continue.

Left Embankment

Condition State: Poor

- Scour of over 40% of embankment.

Performance Deficiency: Unstable Embankment

- Embankment has collapsed. Stability of approach is critically affected.

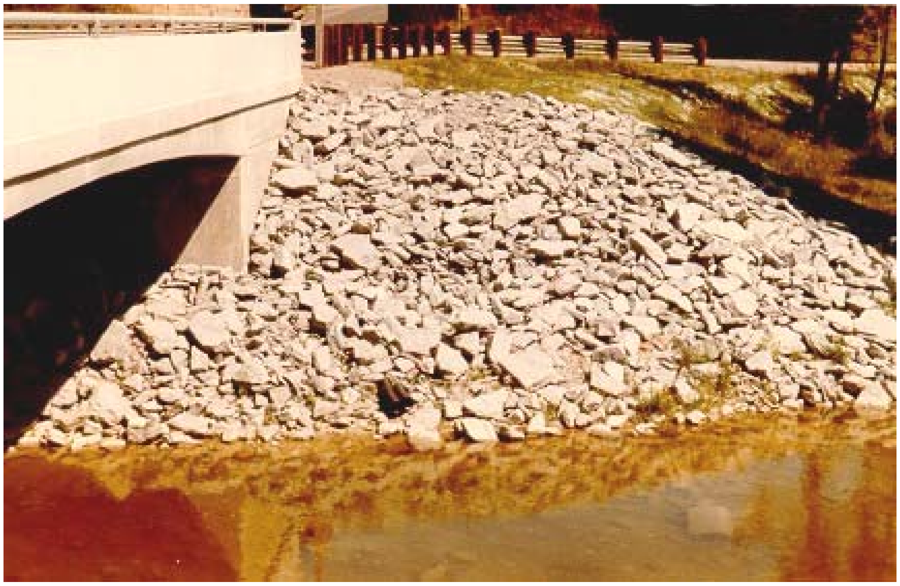


Figure 8.9(d) Random Rip-Rap Slope Protection

Condition State: Excellent

- No evidence of material deterioration.

Performance Deficiency: None

Figure 8.9(e) Grass Slope Protection

Condition State: Fair

- Loss of grass to over 20% of embankment.

Performance Deficiency: Unstable Embankment

- Loss of protection to 20% of the embankment.

Figure 8.9(f) Cast-In-Place Concrete Slope Protection

Condition State: Excellent

- No material deterioration of concrete slabs.

Performance Deficiency: Continuing Settlement; Continuing Movement

- A few areas of minor movement and settlement.

Figure 8.9(g) Precast Concrete Slope Protection

Condition State: Good

- Less than 20% of the slabs broken.

Performance Deficiency: Continuing Settlement; Continuing Movements

- Severe settlement and movement of the slope protection.

Figure 8.9(h)   Streams

Condition State: Poor

- Degradation of stream bed to bottom of footing.

Performance Deficiency: Flooding/Channel Blockage

- Maximum high water marks above soffit of beams.

Figure 8.9(i)   Streams

Condition State: Poor

- Aggradation of right bank and erosion of left bank resulting in severe change in stream alignment and flow at the structure.

Performance Deficiency: Undermining of Foundation

- Stream encroaching against wingwall and substructure with severe erosion of embankment and scour under the foundation.

Figure 8.9(j) Streams

Condition State: Fair

- Medium aggradation and siltation of stream bed with moderate growth of vegetation.

Performance Deficiency: Flooding/Channel Blockage

- Channel blockage reducing opening at structure.

Figure 8.9(k) Streams

Condition State: Poor

- Aggradation of stream bed having a severe effect on stream flow at the structure.

Performance Deficiency: Flooding/Channel Blockage

- Partial blockage of the opening at the structure.

Figure 8.9(l)   Streams

Condition State: Poor

- Very severe deposition of debris after a flood.

Performance Deficiency: Flooding/Channel Blockage

- Debris carried and deposited against structure after a flood causing substantial damage to piles and blocking stream flow.

Figure 8.9(m)   Streams

Condition State: Fair

- Medium local aggradation of the streambed.

Performance Deficiency: Flooding/Channel Blockage

- Flooding of stream over deck occurring every year. Very severe damage to structure by debris carried during flood.

8.10 - FOUNDATIONS

Figure 8.10(a) Foundation

Condition State: Poor

- Localized area with spalling and disintegration. This deterioration should be included with the “Abutment Wall” element.

Performance Deficiency: None

- No visible movement of footing, abutment or superstructure. Loss of section not affecting foundation capacity.

Figure 8.10(b) Foundation

Condition State: Not Applicable

Performance Deficiency: None

- Previous settlement of wingwall has stabilized.

Figure 8.10(c) Foundation

Condition State: Not Applicable

Performance Deficiency: None

- Movement of foundation has stabilized. It has produced wide cracks in abutment but has not affected the stability of the abutment.

Figure 8.10(d) Foundation

Condition State: Not Applicable

Performance Deficiency: Continuing Movements

- Continuing increasing movement of foundation has affected stability of the pier and the superstructure.

8.11 - JOINTS

Figure 8.11(a)   Finger Plate Expansion Joint

Condition State: Good

- Light rust.

Performance Deficiency: Jammed Expansion Joint / Pedestrian/Vehicular Hazard

- No room for further expansion, joint alignment poses danger to traffic.

Figure 8.11(b)   Compression Seal Joint

Condition State: Poor

- Seal is leaking.

Performance Deficiency: None

Figure 8.11(c) Paved-Over Joint

Condition State: Poor

- Significant cracking of asphalt pavement. Joint is leaking.

Performance Deficiency: Rough Riding Surface

- Rough ride across the joint.

Figure 8.11(d) Ethylene Vinyl Acetate Seal

Condition State: Poor

- Seal is leaking.

Performance Deficiency: None

Figure 8.11(e) Multiple Seal Joint

Condition State: Poor

- Seal torn and joint is leaking.

Performance Deficiency: None

Figure 8.11(f) Rubber Cushion Joint

Condition State: Poor

- Joint is leaking.

Performance Deficiency: None

Figure 8.11(g) Horizontally Bolted Seal

Condition State: Good

- Light abrasion of the seal due to debris.

Performance Deficiency: Jammed Expansion Joint

- Deck movement severely restricted by debris.

Maintenance Needs: Bridge Cleaning

- Debris should be cleared as part of general maintenance.

8.12 - PIERS

Figure 8.12(a) Concrete Pier Cap

Condition State: Poor

- Very severe spalling and corrosion of exposed reinforcement.

Performance Deficiency: Load Carrying Capacity

- An evaluation is required to determine the extent of load carrying capacity.

Figure 8.12(b) Concrete Pier Column

Condition State: Poor

- Very severe delamination and spalling of the column, with exposed reinforcement.

Performance Deficiency: None

- Section loss will have minimal effect on load carrying capacity.


Figure 8.12(c)   Steel Pier Bent Base

Condition State: Fair

- Medium corrosion; 5% to 10% loss of section locally.

Performance Deficiency: None

- Component capacity marginally affected by loss of section.


Figure 8.12(d)   Wood Trestle

Condition State: Good

- Light decay in piles.

Performance Deficiency: None

- No evidence of movement. Piles satisfactorily supporting load without distress.

Figure 8.12(e) Masonry Pier

- **Condition State: Fair**
  Medium crack in stone.

Performance Deficiency: None

- Previous movement has stabilized.

Figure 8.12(f) Disc Bearing

Condition State: Good

- Light rusting and stainless steel sliding plate is separating slightly.

Performance Deficiency: None

- Movement capacity affected less than 10%.

8.13 - RETAINING WALLS

Figure 8.13(a)   Precast Concrete Retaining Wall

Condition State: Fair

- Medium Cracking of Precast Units.

Performance Deficiency: None

- No evidence of movement. Wall satisfactorily retaining fill.

Figure 8.13(b)   Bag Mortar Retaining Wall

Condition State: Good

- Minor loss of material at the joints.

Performance Deficiency: Continuing Movement

- A few locations of local minor movement. Wall satisfactorily retaining fill. Vegetation growth should be removed as part of general maintenance.

8.14 TRUSSES/ARCHES

Figure 8.14(a) Steel Through Truss Connection

Condition State: Poor

- Severe corrosion over a plan area greater than 10%. Severe connection deficiency exists.

Performance Deficiency: Load Carrying Capacity

Possible loss of load carrying capacity. An evaluation is required to determine the extent of strength reduction.

Figure 8.14(b) Sway Frame Connection.

Condition State: Fair

- Medium corrosion over more than 40% of the connection. No connection deficiency since no areas of severe corrosion exist on gusset.

Performance Deficiency: None

- Minimal loss of strength due to corrosion.

Figure 8.14(c) Vertical Member of Steel Through Truss

Condition State: Poor

- 15% to 20% of cross section removed to install guide rail.

Performance Deficiency: Load Carrying Capacity

- Possible loss of load carrying capacity due to loss of section, and subsequent buckling. An evaluation is required to determine the extent of strength reduction.

Figure 8.14(d) Concrete Bowstring Arch

Condition State: Poor

- Very severe scaling of arch rib.

Performance Deficiency: None

- Marginal loss of performance. Material defects unlikely to cause reduction in load carrying capacity.

Figure 8.14(e) Concrete Spandrel Arch

Condition State: Poor

- Very wide crack in the arch rib.

Performance Deficiency: None

- Crack extends about 100 mm into the rib. Material defects unlikely to cause reduction in load carrying capacity.

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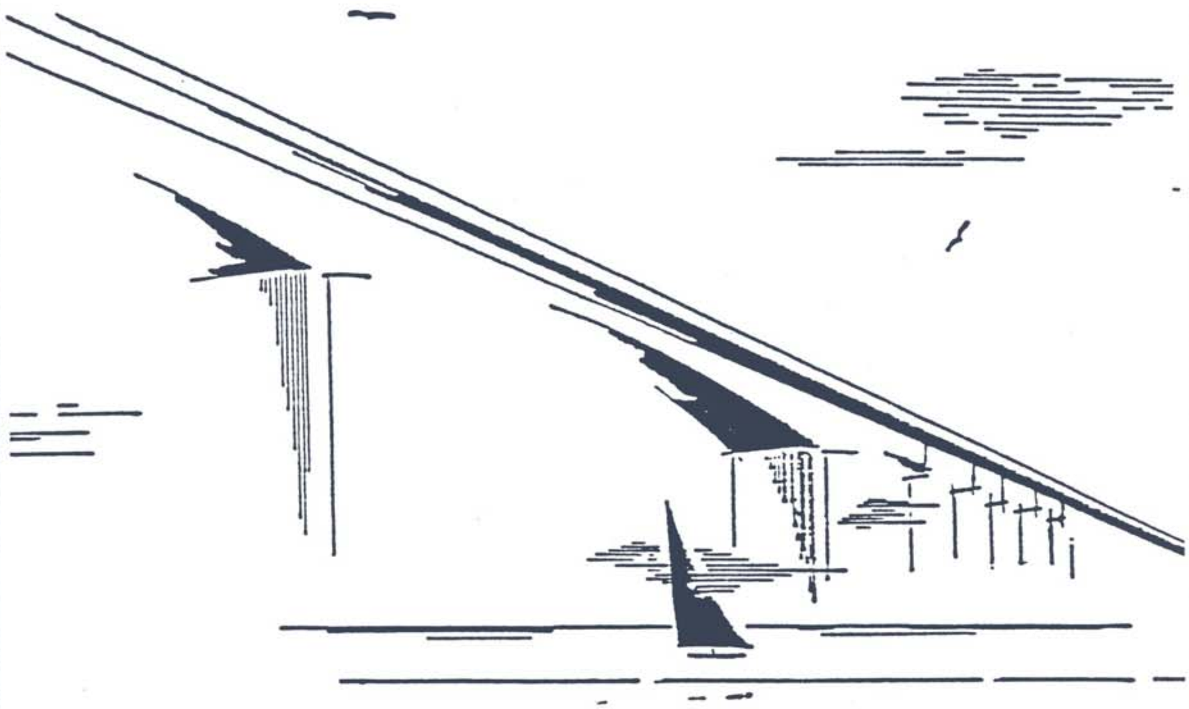

ONTARIO
STRUCTURE INSPECTION MANUAL

Part 3 – Additional Investigations

PART 3 – ADDITIONAL INVESTIGATIONS

Contents **Page**

3.1 INTRODUCTION

During the course of the inspection, the inspector may feel that more detailed information on the structure is required. The presence of severe material defects or performance deficiencies may necessitate additional investigations to be done. When requesting an additional investigation, the inspector should also indicate the time frame for completion of the investigation as described in Section 7 of Part 2.

In addition, an Owner may undertake special studies to determine if any components of a structure are “functional obsolete”. A component is considered to be functionally obsolete if it were originally designed and constructed using a Standard or Code that has since changed. This type of information is usually recorded in the form of “appraisal indices” as described in Section 3.8.

3.2 MATERIAL CONDITION SURVEYS

Condition surveys involve the detailed measurement and documentation of areas of defects and deterioration that exist on a structure. Procedures more precise than visual inspection techniques are usually employed. Examples of these procedures are: material testing of samples, half-cell surveys, etc. For additional information on condition surveys for concrete elements, refer to the Structure Rehabilitation Manual.

As a general guide, material defects in the proportions listed in Table 1 would trigger a detailed condition survey to be done. It should be noted that Condition Surveys are also carried out on structures that are programmed for rehabilitation or sometimes when an evaluation is to be carried out.

Table 1: Material Condition Survey Triggers

Condition Survey Type	Description	Condition Survey Trigger	References
Concrete Deck (Asphalt or Concrete surface)	Involves the testing of various core samples, sawn samples and the delineation of delaminated areas and areas of high corrosion potential (using half-cell survey)	5% of element in "Poor" Condition State	Structure Rehabilitation Manual
Non-destructive Delamination Survey of Asphalt Covered Decks	Involves the delineation of delaminated areas using non-destructive testing techniques such as Ground Penetrating Radar, Impact Echo testing, etc	5% of element in "Poor" Condition State	Structure Rehabilitation Manual
Concrete Substructure	Involves the testing of various core samples, etc, and the delineation of delaminated areas and areas of high corrosion potential (using half-cell survey)	10% of element in "Poor" Condition State	Structure Rehabilitation Manual
Wood Substructure or Superstructure	A detailed investigation of the wood components using techniques such as probing, drilling, coring, etc.	10% of element in "Poor" Condition State	Part 4 of this manual
Structural Steel Coating	A detailed survey of the condition of the coating to confirm the feasibility of over-coating. The survey involves testing coating adhesion, dry film thickness, etc. If deterioration is still in the early stages (Combined area of Fair and Poor greater than 25%, and Poor is less than 10% at the visual inspection stage), "over-coating" of the steel may be a viable rehabilitation option. This involves cleaning the surface with a wire brush and "over-coating" the entire surface. If deterioration exceeds the threshold, traditional coating techniques (sandblasting the surface, priming, etc,) would probably have to be used.	25% of combined area in "Fair" and "Poor" Condition States and also the percentage in Poor less than 10%.	Structural Steel Coating Manual

3.3 UNDERWATER INVESTIGATIONS

Underwater inspection shall be considered for components under water where the depth or clarity of water does not permit a satisfactory visual inspection. They are also carried out when there is evidence of scour or undermining of the structure foundations. For scour prone structures, underwater inspections should normally be carried out at five year intervals, unless information is available to justify either reducing or increasing this interval. Underwater inspections should only be carried out by qualified divers familiar with the following CSA Standard: "Occupational Safety Code for Diving Operations". Additional information on Underwater Inspections is contained in Part 5 of this manual.

3.4 FATIGUE INVESTIGATIONS

Some jurisdictions have a specific fatigue inspection program for their fatigue prone bridges. This involves performing regular close-up inspections of steel components and by employing Non-destructive testing techniques, when necessary (See Part 4 of this manual). The prioritizing of bridges that require a fatigue type inspection is done by carrying out a study of the steel bridge inventory. It involves reviewing details, construction techniques, materials, etc. The ranking of bridges can be reflected in a fatigue index as described in Section 3.8.

Fatigue investigations can also be triggered if fatigue cracks are identified during a biennial inspection.

3.5 SEISMIC INVESTIGATIONS

During the course of a detailed visual inspection, the inspector may observe situations that may place structures at risk if they are in a high seismic zone. The inspector may notice:

- Rocker bearings that are severely inclined and may be in danger of collapse during a seismic event
- The superstructure may be close to the edge of its bearing seats. The bearing seat lengths may be inadequate during a seismic event.

If some of these observations are made, the inspector can request that a detailed seismic investigation be done. The inspector should also review the Seismic Index if a general study has been done as described in Section 3.8.

3.6 STRENGTH EVALUATION – LOAD CARRYING CAPACITY

To determine the load carrying capacity of a structure, a strength evaluation should be performed. It is extremely difficult to determine a load limit with only visual inspection information. Bridge plans should be reviewed and a structural analysis should be performed. If bridge plans do not exist, measurements should be taken, similar bridge plans can be reviewed, assumptions can be made and some calculations should be done. In addition, for steel structures, it is often necessary to measure the thickness of critical members and determine the actual section loss as it varies across the element. This information should be used in the evaluation. For concrete structures, section loss in reinforcing steel should also be measured and accounted for in the evaluation.

3.7 MONITORING OF DEFORMATIONS, SETTLEMENTS AND MOVEMENTS

During a detailed visual inspection, the inspector may have identified elements that have settled, deflected, rotated or tilted. If the movement has stabilized, immediate action is probably not required. In order to determine if movements have stabilized, a monitoring program should be implemented, whereby various measurements are recorded over a period of time and compared to previous measurements. The propagation of cracks in various materials can also be monitored over a period of time.

3.8 APPRAISAL INDICES

Often, an owner undertakes special studies to determine if any of the structures in the inventory have components that are "functionally obsolete". The studies usually consist of specialized inspections in addition to a more rigorous review of structural details, design parameters, current Code requirements, etc. If deficiencies are identified, structures are prioritized using "appraisal indices" and policies are set to address the components that are functionally obsolete. These appraisal indices should be used together with the material defects and performance deficiencies in determining the optimum rehabilitation or replacement option for the structure in question.

Examples of appraisal indices are:

(1) Fatigue
- Identifies fatigue prone structures and sets priorities for close-up visual inspection

(2) Seismic
- Identifies structures with poor seismic details and sets priorities for further seismic evaluations.

(3) Scour
- Identifies structures with poor scour details and sets priorities for further scour investigations/inspections (e.g. Underwater investigations).

(4) Flood
- Identifies structures that are prone to flooding and sets priorities for further flood investigations/inspections or monitoring programs.

(5) Geometrics
- Identifies structures with functionally obsolete details such as lane widths, vertical clearances, horizontal clearances, etc, by comparing the original design with current Code requirements.

(6) Barrier
- Identifies structures with functionally obsolete barriers/railings by comparing the original design with current Code requirements.

(7) Curb
- Identifies structures with functionally obsolete curbs/sidewalks by comparing the original design with current Code requirements.

(8) Load Capacity
- Ranks structures that have been recently evaluated using current Code requirements. The index gives an indication of excess or insufficient load carrying capacity.

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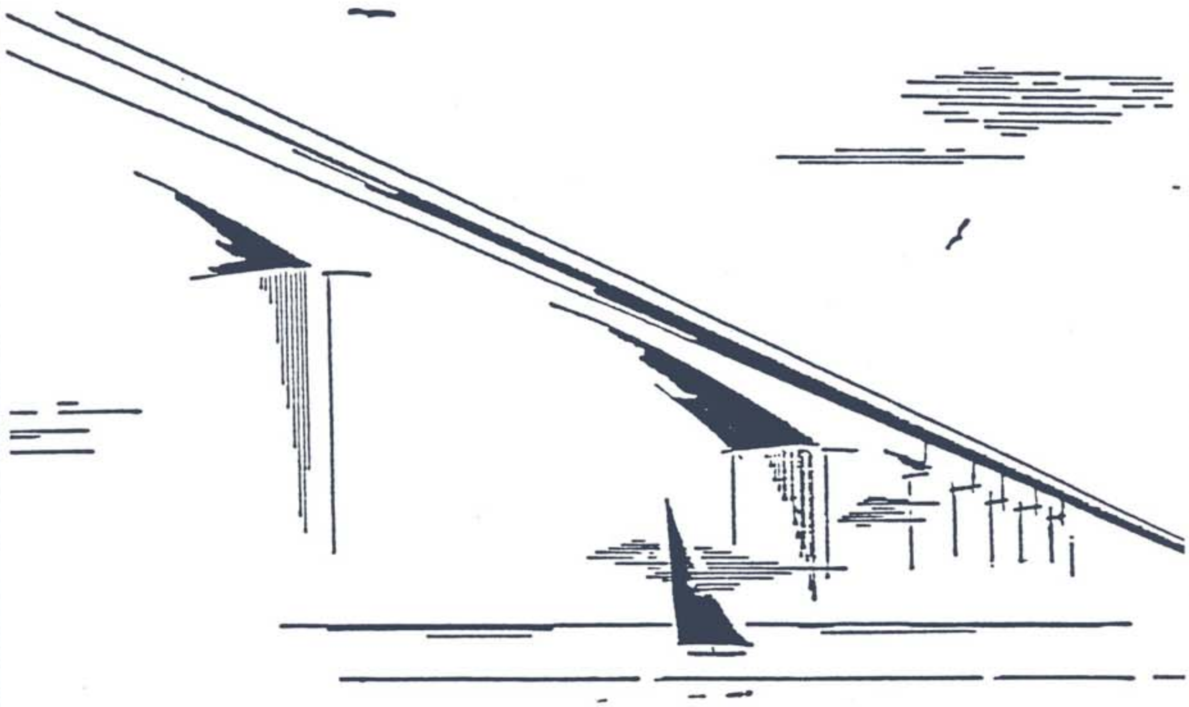

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STRUCTURE INSPECTION MANUAL

Part 4 – Material Condition Surveys

Part 4 - Material Condition Survey

Section 1 - Structural Steel

1.1 Non-Destructive Testing Methods for Detection of Defects in Steel Components

A comprehensive non-destructive testing program of steel bridge components should be carried out whenever the members are cleaned to bare metal for any reason. At this time, a thorough visual examination of all exposed surfaces and connections can be implemented along with an examination of critical areas and components. This can be performed by the use of non-destructive techniques described herein.

Non-destructive testing is a term used to describe a process which allows materials and structures to be examined for defects without changing or destroying their usefulness. A wide variety of techniques have been devised among which the most commonly used, in addition to visual inspection, are:

Liquid penetrant or dye penetrant	(LP)
Magnetic particle	(MP)
Ultrasonic Testing	(UT)
Eddy Current testing	(ET)
Radiographic	(RT)

Of the five methods presented, none can satisfactorily identify all defects, each has its limitations and the accuracy that can be achieved with all the equipment under laboratory conditions can seldom be obtained in the field due to normally unfavourable site conditions.

A large variety of defects can be identified using non-destructive testing procedures and these are classified in three categories;

- Primary Inherent Defects
- Secondary Fabrication Defects
- In-Service Defects

Primary inherent defects in the materials used in the manufacturing of steel structures (plates, forgings, castings structural shapes, etc.) conform to the applicable standards. The standards permit minor surface discontinuities and non-significant internal defects which are smaller than the minimum allowable size. These defects, which remain in the finished product and are smaller than the maximum allowable defect size, usually have little effect on the strength of the member.

Secondary fabrication defects can be introduced into the material during fabrication. Processes used to produce the final product may introduce different defects or discontinuities to the structure. These are usually, but not always, identified through quality control procedures and are rectified by the fabricator. However, these defects are sometimes missed and should always be considered in subsequent inspections.

In-service defects arise from cyclic stresses or excessive loading which result in metal fatigue. This fatigue leads to the initiation of cracks which propagate and cause component failure. General corrosion of a component results in section loss reducing the ability of the component to support the design load. Pitting Corrosion combined with cyclic stresses causes stress corrosion cracking. This results in the reduction of a components strength and ability to carry design loads.

Defects remaining in the finished structure may, due to their shape, location and service environment, become stress raisers. These stress raisers compromise structural integrity.

All of the various non-destructive techniques can be applied in the field to identify and evaluate defects although some techniques are more suitable than others. The following sections describe each of the procedures, along with advantages and disadvantages in field applications.

1.1.1 Liquid Penetrant Testing.

The liquid penetrant method is commonly used in both shop and field to reveal defects that are open to the surface. It is simple to carry out, involves little time, is inexpensive and is easily interpreted. The process consists of the following:

- The surface of the metal is carefully cleaned with a wire brush or by water blasting to remove all loose scale, rust, etc. followed by solvent cleaning to remove any surface contaminants. Grinding or sanding of the surface may burr over or otherwise obscure defects.

- A liquid penetrant, a brilliantly coloured penetrating oil, is applied to the cleaned surface and allowed to seep into the surface defects for thirty minutes or more.

- Excess penetrant is then removed and a developer agent is sprayed onto the surface.

- The developer dries to a white chalky coating and remains unchanged in the absence of any defects. Where surface defects do exist, the penetrant is drawn to the surface by capillary action and stains the developer.

The surface can then be visually examined for cracks or other surface defects which will be revealed by brightly coloured stains on the white surface.

The dwell time of the penetrant can be varied to detect cracks of different widths, the finer the crack the longer the dwell time. Fluorescent penetrants can be used with ultraviolet light to detect cracks wider than about 3 microns. The sequence for liquid penetrant application and typical images are shown in figure 1.1.1a. to figure 1.1.1c

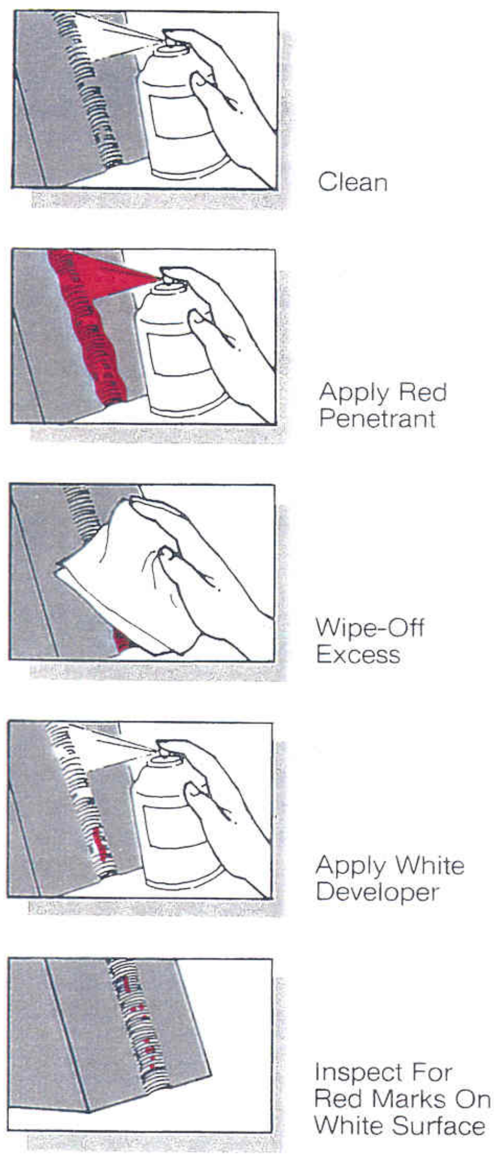

Figure 1.1.1a Steps required for applying liquid penetrant

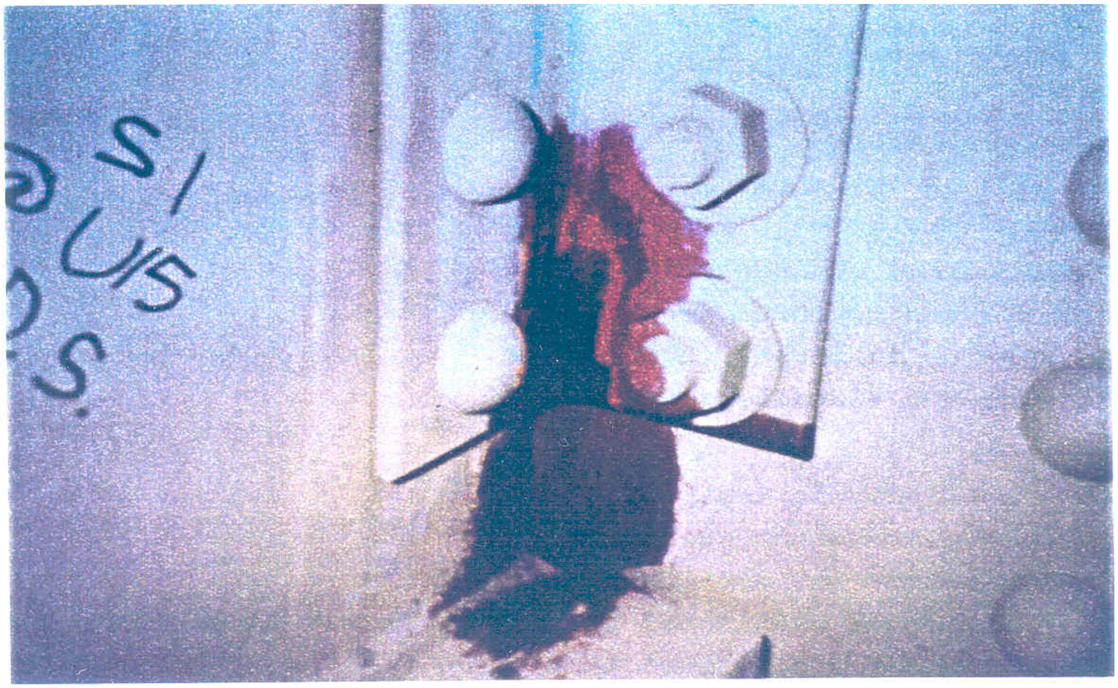

Figure 1.1.1b Metal surface after liquid penetrant application.

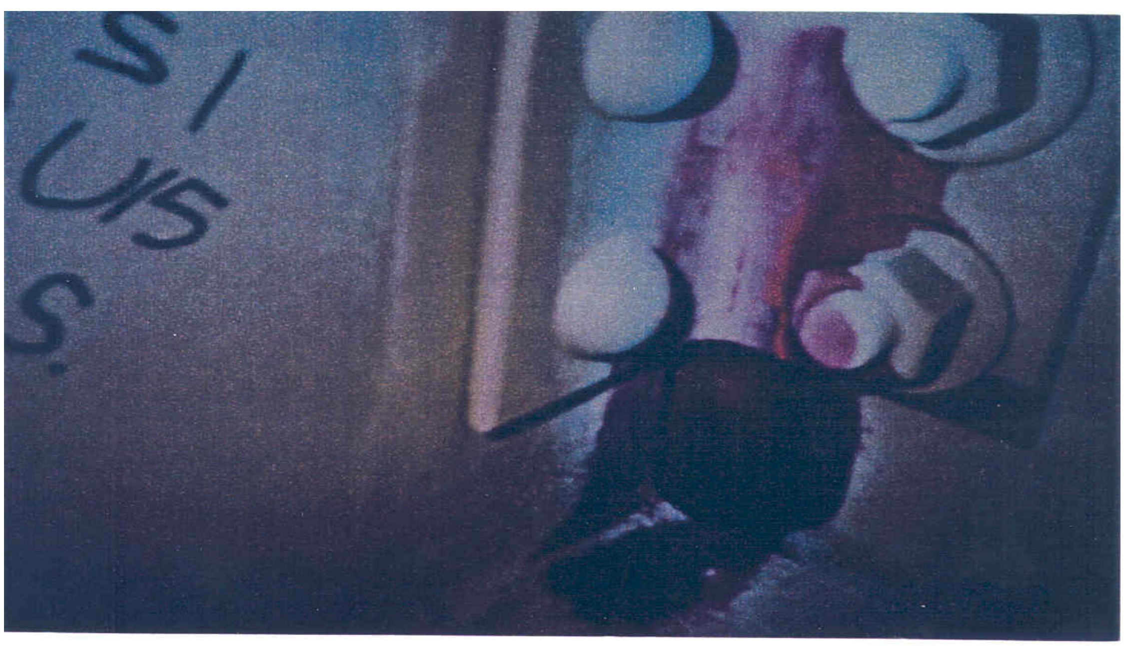

Figure 1.1.1c Surface after developer has been applied. A crack was detected by the small thin red line (bottom right of the weld).

Advantages

- Highly portable
- Relatively inexpensive
- Can be applied to a wide variety of non-porous surfaces
- Rapid method of inspection
- Results can be recorded photographically
- No special equipment required
- Results are visually apparent

Disadvantages

- Does not indicate depth of flaw
- Surface must be accessible
- Cannot detect any sub-surface defects
- Test site must be cleaned thoroughly before inspection
- Post cleaning may be necessary

Standards

CGSB 48-GP-9M	Certification of Non-Design Personnel
CGSB 48-GP-12M	Liquid Penetrant Inspection
ASTM-E-165	Standard Practice for Liquid-Penetrant Inspection Method.
ASTM-E-1770	Standard Method for Visible-Penetrant Examinations Using the Solvent Removable Penetrant

1.1.2 Magnetic Particle

Magnetic Particle Testing is used to detect surface and near surface defects.

When a ferromagnetic material is subjected to a magnetic field, magnetic flux lines are generated in specific directions, depending on the placement of the contact electrodes or magnetic poles. When a defect within the field lies generally at right angles to the flux lines, the field will be distorted and some of the magnetic flux will leak out of the steel at the defect. Fine magnetic particles (low retentivity iron powder) distributed over the surface are attracted by the leakage field and held magnetically to form an outline of the defect.

The area to be examined is magnetized by two current carrying copper prods held against the surface of the component, a short distance apart to produce a circular magnetic field. As only defects which are perpendicular to the magnetic flux lines, can be detected, the prods must be moved about and re-positioned to ensure that all defects are located regardless of orientation.

Both AC and DC electric current is suitable for magnetizing steel components. Surface defects are most readily detected with AC magnetization. DC magnetization provides greater penetration for detection of subsurface defects.

Electromagnetic yokes produce suitable magnetic fields and are highly portable.

Figure 1.1.2a shows units used for producing a magnetic field and figure 1.1.2b illustrates how the yokes are used in conjunction with particle application for inspection.

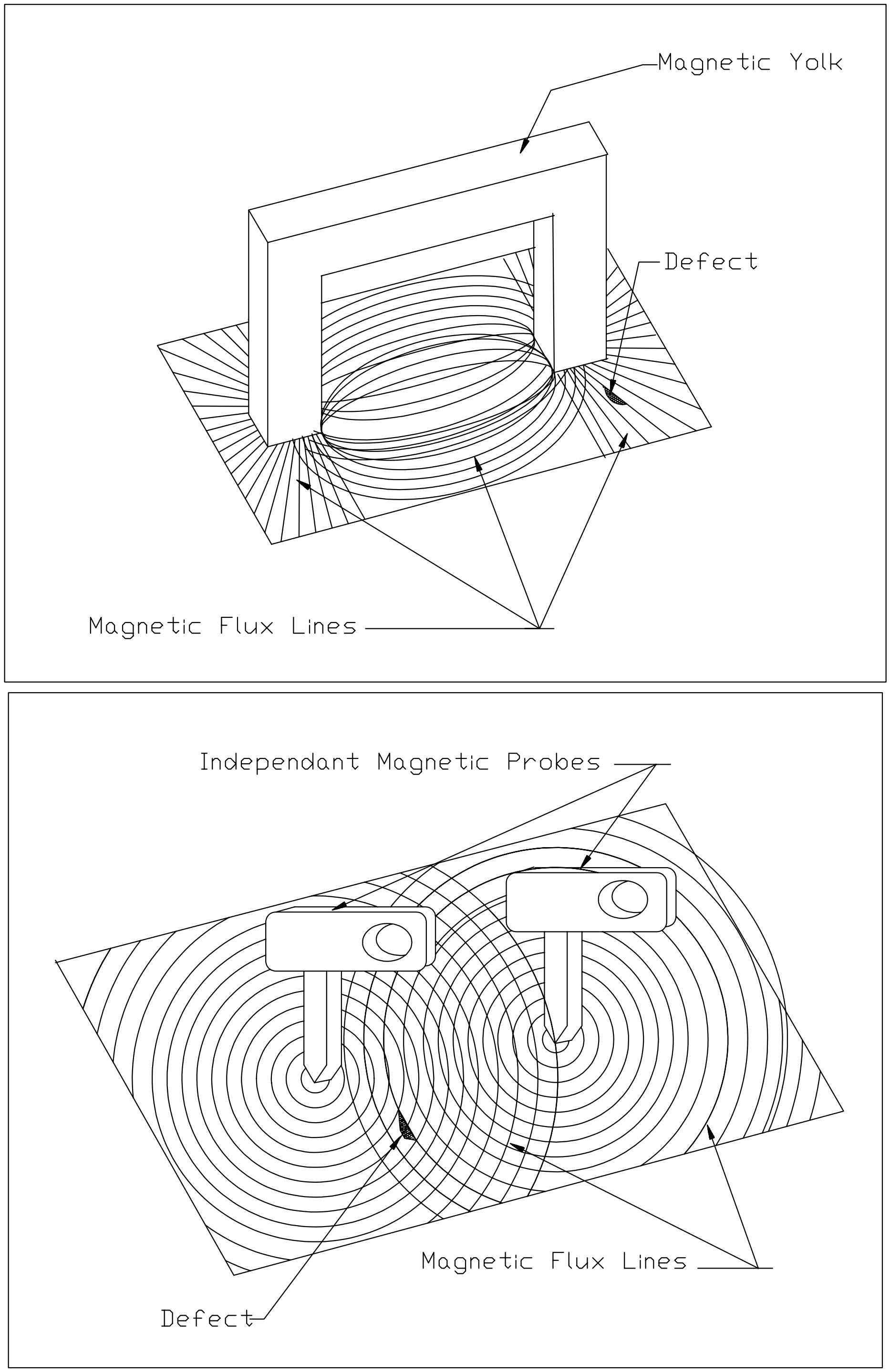

Figure 1.1.2a Typical units used for generating magnetic fields to locate any defects. Top: Yoke; Bottom: Prods.

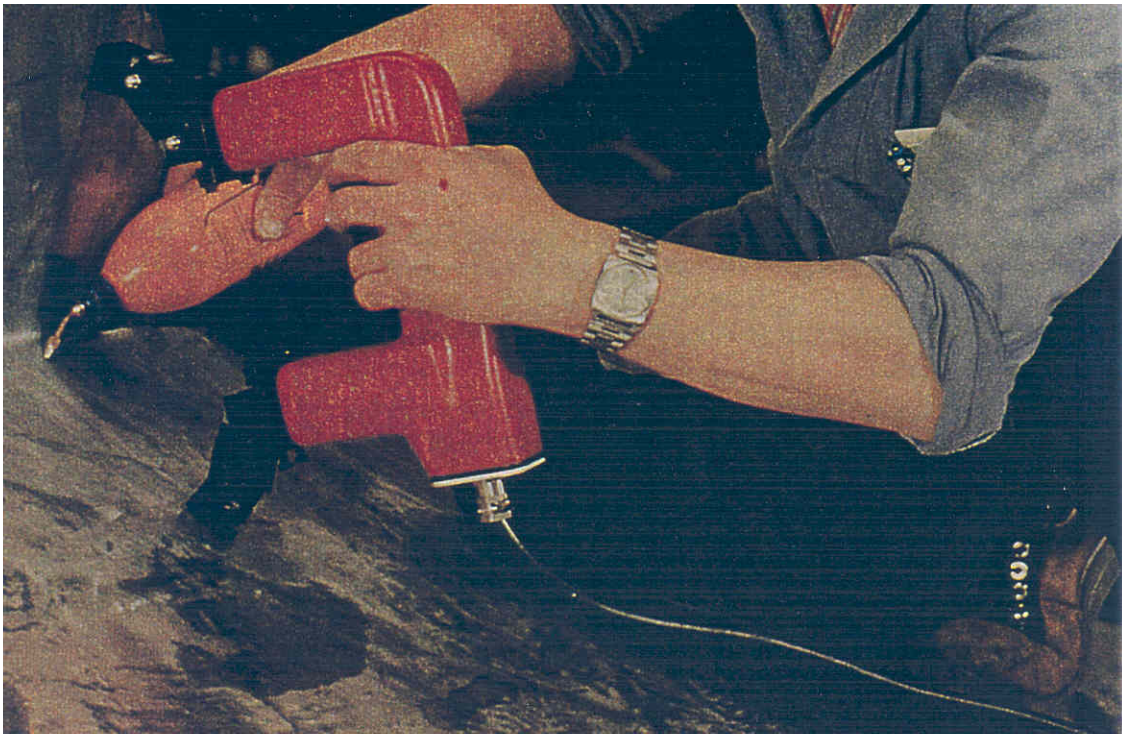

Figure 1.1.2b Typical application of magnetic particles and field generator (yoke).

Advantages

- Portable and inexpensive;
- Can detect fine and shallow surface cracks;
- Fast and relatively simple to apply;
- Few limitations on size and shape of parts or structures;
- Surface cleanliness and cleaning methods not as important as for liquid penetrant method.

Disadvantages

- Surfaces must be reasonably smooth to avoid non-relevant indications;
- Requires removal of surface materials which may interfere with the ability to magnetize the area. (Generally, the area should be cleaned of debris and loose materials. Non-conductive coatings must be removed where the prods contact the metal.);
- Only detects surface defects with certainty, does not indicate depth of cracks and defects.
- Some sub-surface defects are detectable but indications are diffused;
- Direction and strength of the magnetic field is critical, flux lines should be normal to the plane of a defect;
- Prod method of magnetization can cause arc burns and possible cracks;
- Demagnetization is necessary when magnetic particles may interfere with working metal surfaces, threads on bolts or subsequent painting operations;
- Can only be applied to accessible surfaces;

Standards

CGSB 48-GP-8M	Certification of Non-Destructive Testing Personnel
CGSB 48-GP-11M	Manual on Magnetic Particle Inspection
ASTM-E109-80	Dry Powder, Magnetic Particle Inspection
ASTM E709	Standard Practice for Magnetic Particle Examination

1.1.3 Ultrasonic Testing

Ultrasonic testing is a method in which high frequency sound waves are introduced into a material for the detection of surface and internal defects. They pass through the material and are reflected at interfaces or boundaries such as flaws such as cracks, slag inclusions, porosity etc., or the back surface of the material. The reflected waves returning to the source can be displayed as pulses or signals on the screen of a cathode ray tube. The pulses or signals relate to the transit time of the sound. The travel time of the returning pulses is a measure of the distance to the interface of the defect.

The ultrasonic method is used to detect cracks and various other types of planar defects in wrought materials, to examining welds in fabricated components for cracks, slag inclusions and porosity, and for measuring residual wall thickness of corroded components.

The ultrasonic system is comprised of a high frequency pulse generator, transducer, receiving amplifier and CRT screen. These components allow for detection and location of defects. By various scanning movements in the area of a defect, orientation, size, shape and nature can be determined through interpretation of the reflected pulses displayed on the screen of the instrument. Ultrasonic systems can detect discontinuities that are larger than one half of the wave length of the signal. A system operating at 5MHz will detect defects larger than about 0.5mm.

A schematic of ultrasonic testing is shown in figure 1.1.3a and the application of the instrument in figure 1.1.3b & 1.1.3c.

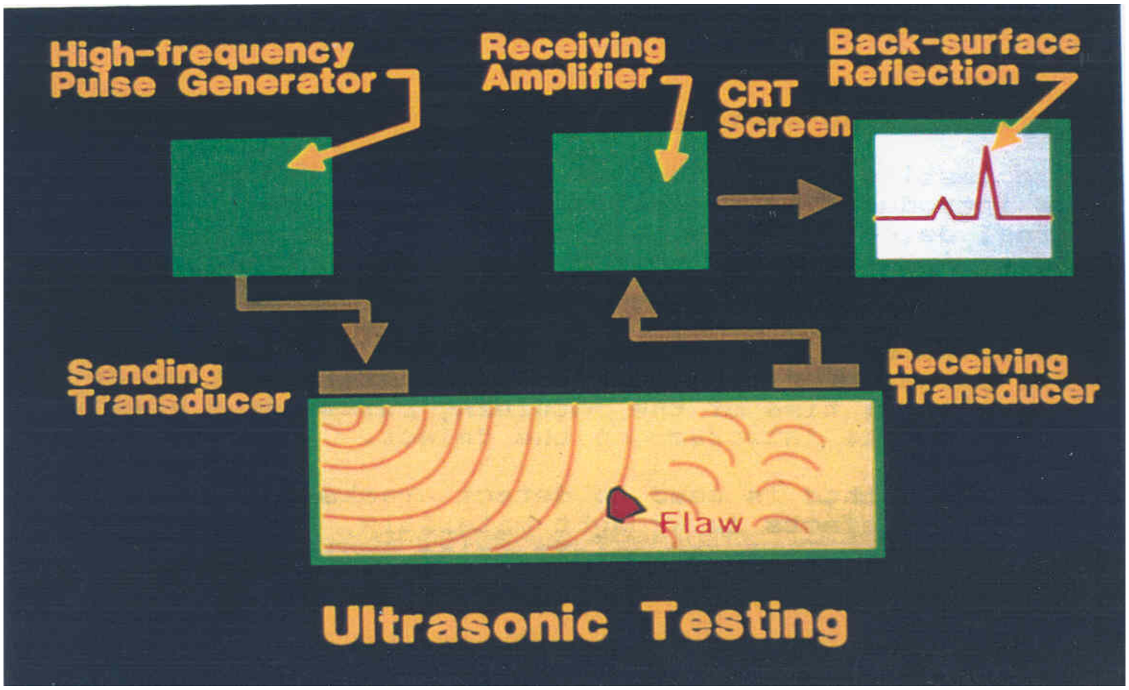

Figure 1.1.3a Schematic of ultrasonic testing equipment
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Figure 1.1.3b Application of ultrasonic testing equipment. Component was being inspected for voids and metal defects.

Figure 1.1.3c Ultrasonic testing of a bridge pin.

Advantages

- Detects the depth and location of cracks and planar defects;
- Very sensitive and can detect small defects such as inclusions;
- With adjustments in procedure (angle-beam method and contact pulse reflection) can detect internal defects and fatigue cracks;
- Few restrictions on size of work piece;
- Ideal for testing wrought materials and welds;
- Requires access to one surface of the test piece;
- Highly portable;
- Equipment is relatively inexpensive;
- Can be fully automated for scanning uniform shapes.

Disadvantages

- Rough or uneven surface must be ground smooth.
- Interpretation of results dependent on skill, knowledge and experience of operator.
- No permanent record of the observations. (Methods have been recently developed to digitize the screen image which can then be computer enhanced and/or printed.)
- High noise levels are produced by coarse grain structures such as cast iron which reduce test efficiency.

Standards

CGSB 48-GP-7M	Certification of Non-Destructive Testing Personnel
CGSB 48-GP-6M	Recommended Practices for Ultrasonic Examination of Structural Welds
ASTM E164	Standard Recommended Practice for Ultrasonic Contact Examination of Weldments

1.1.4 Eddy Current

Eddy current testing is a method based on the principles of electromagnetic induction. The component or part thereof to be tested is placed within or adjacent to a coil which is excited by an alternating current.

As the induced current fluctuates, an eddy current is produced which flows in a closed loop inside the test material. The flow of this eddy current is affected by the electrical properties of the part and the existence of defects distorts the electromagnetic field within the part.

When defect free material is being tested the eddy current flow remains uniform. In the presence of a crack or other defect, the eddy current flow is impeded and changes direction, which in turn alters the electromagnetic field. Eddy current instruments are designed to detect and monitor these changes.

Advantages

- Can be used for rapid inspection of planar shapes;
- Ideally suited for non-ferrous materials
- Contact of coil or probe with surface not necessary but a consistent separation must be maintained;
- Thin, uniform coatings do not have to be removed;
- Detects very small discontinuities;
- The size of the defect can be estimated;
- No couplants or post cleaning needed;
- Good method for sorting materials, checking heat treatment and detecting hardness variations.

Disadvantages

- Not suitable for complex shapes;
- Shallow penetration of parts, detects surface and subsurface defects only;

- Needs reference samples for comparison purposes;
- Material must be electrically conductive;
- Surfaces must be smooth and uniform;
- Skilled and experienced technicians required to interpret the indirect test results.

Standards

CGSB 48-GP-13M	Standard for: Certification of Non-Destructive Testing Personnel
CAN/CGSB 48.14-M86	Advanced Manual for Eddy Current Test Method

1.1.5 Radiographic Testing

This method is based on the ability of ionizing radiation in the form of X-rays or Gamma Rays to penetrate solid materials to produce an image on film or a fluorescent screen (figure 1.1.5a).
The radiation is mostly absorbed when passing through sound and thick metal while it will pass more readily through cracks, defects and thinner material. Any differences in density due to inclusions or gas cavities or thickness variations in the part being examined cause differences in the absorption rates of the penetrating radiation. The resulting images on the film appear in various shades of gray, depending upon the amount of radiation reaching the film. Since cracks or defects absorb less of the available radiation they create a darker image than the sound material.

The radiograph shown in figure 1.1.5b illustrates a typical X-ray radiograph of a metal arc weld with slag inclusions.

Under ideal field conditions, radiographic inspections can be used on most types of solid materials to reveal defects with depths or thicknesses greater than about 2% of the thickness of the material being examined. Cracks with depths of about 1.0mm or more should be detected under normal conditions when the plane of the crack is parallel to the direction of radiation.

This method is not well suited for testing in field conditions. It should, however, not be eliminated as a test method. The use of ultrasonic testing would be a suitable test method in place of radiographic testing.

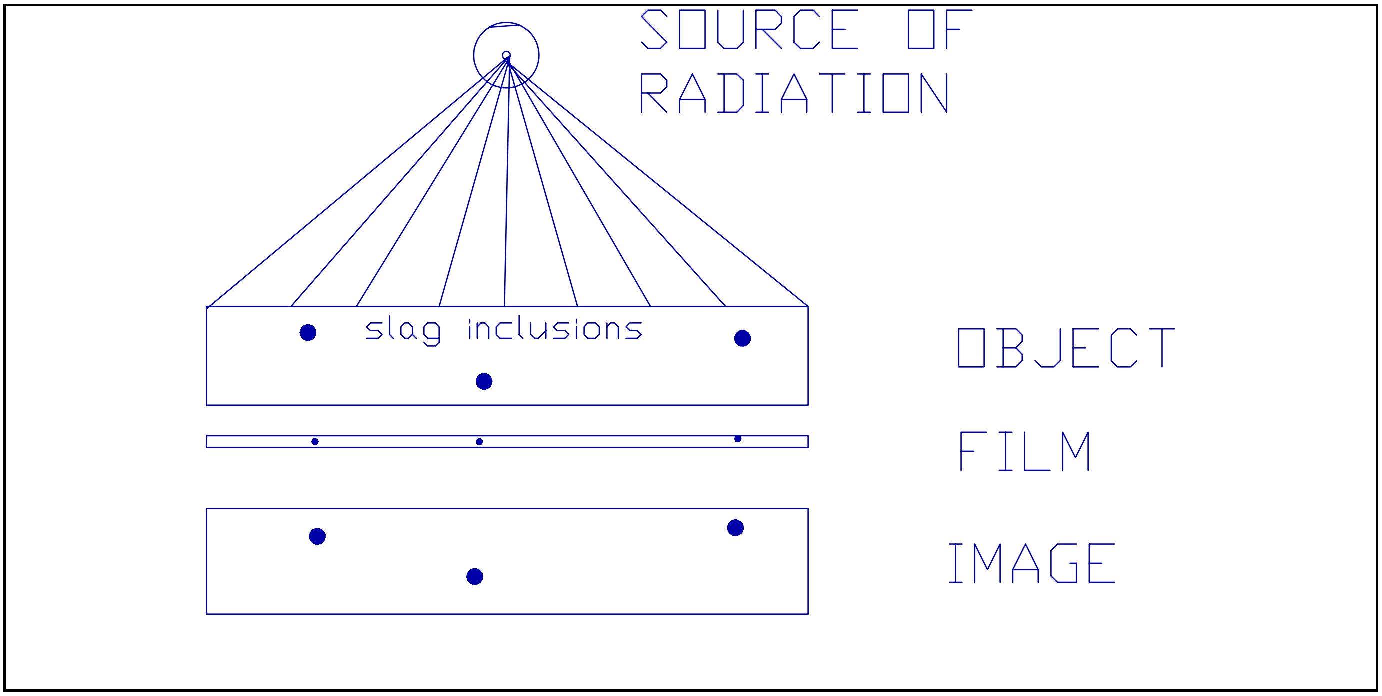

Figure 1.1.5a Schematic of typical radiographic equipment.

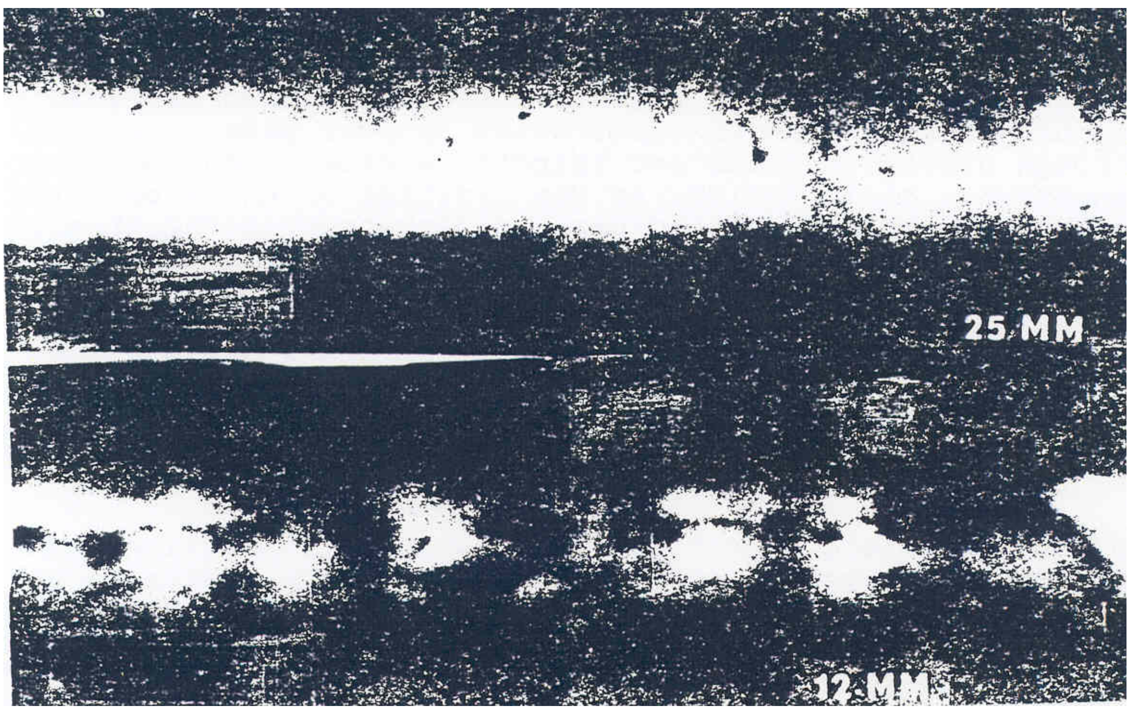

Figure 1.1.5b Radiograph of a double vee groove metal arc weld in steel. The dark contrasting spots are slag inclusions. The top image has acceptable slag inclusion the bottom image was considered severe.

Advantages

- Well suited for the detection of open cracks and internal defects particularly in welds (inclusions and porosity);
- Detects cracks oriented approximately parallel to the axis of the rays;
- Permanent record of defects can be produced on film;
- Image is geometrically correct relative to the size, shape and location of the defect and area examined;
- Method and equipment well known and accepted;
- Gamma ray equipment is more portable while the less portable x-ray equipment can produce better contrast and definition of defects.

Disadvantages

- Equipment is hazardous and subject to rigid government controls. GAMMA RADIATION CANNOT BE TURNED OFF! Radiation sources must be heavily shielded;
- Not able to determine the depth of a defect;
- Cannot detect defects oriented perpendicular to the axis of the rays. Varying degrees of detection capabilities for other orientations relative to the axis of the rays;
- Both faces of test area must be accessible;
- Equipment is bulky and may be difficult to use in areas with limited space or restricted access;
- Not well suited to the detection of fine, tight cracks.
- Testing is expensive, particularly in the field.

Standards

CGSB 48-GP-4M	Certification of Non-Destructive Testing Personnel
CGSB 48-GP-5M	Manual on Industrial Radiography

1.1.6 Comparison of Non-Destructive Methods

All of the foregoing non-destructive testing techniques can be used to evaluate defects in bridge structures but some are more readily used than others. Which method or methods that are to be used will depend entirely upon the information to be derived.

Liquid penetrants are ideally suited in confirming the presence of a surface defect such as a crack which has been identified by some surface anomaly during a visual inspection. The technique will confirm a discontinuity on the surface of a component and show its size but with no indication of the depth. It is not particularly suited for a comprehensive testing program of welds and assemblies.

Magnetic particle testing is a simple method for quickly evaluating extensive welds and surface areas. It too is most suited to detecting surface discontinuities although some sub-surface defects may also be detected if they are close to the surface. As with liquid penetrants, this method will delineate the aerial extent of a defect but will provide no indication of the depth.

Ultrasonic techniques provide a means to identify and measure both surface and subsurface discontinuities quickly and economically although specific procedures are required that are unique to the component under test. Defects within the material appear as anomalies on the screen and through interpretation by the testing technician, the size of the defects can be estimated.

Eddy current testing will provide accurate detection of surface and near surface defects but requires the surface to be quite smooth; any irregularities complicates the interpretation of the results. This method is ideally suited to shop inspection of large planar surfaces but as the geometry of the component under test becomes more complex the observations become more difficult to interpret. The success of this technique is highly dependent upon the experience and expertise of the testing technician.

Radiography is a major non-destructive testing method which is routinely applied to the examination of welds and assemblies during fabrication. It is ideally suited to the detection of voids, inclusions, porosity, open cracks etc., where both faces of the component are accessible. A photographic image of a defect is produced illustrating its extent but not its depth. The equipment is expensive and requires special precautions to protect against radiation hazards, as is generally not recommended for use in the field.

Table 1.1.6 gives a relative comparison of each test method to assist the user in selecting a suitable method for a particular application.

Table 1.1.6 Comparison of Non-Destructive Methods

	Inspection Method				
	Liquid Penetrant	Ultra-sonic	Magnetic Particle	Eddy Current	Radiography
In-Service					
fatigue Cracks	G	G	G	G	P
Stress Corrosion	G	G	G	N	F
Corrosion Pits	F	G	N	N	G
Surface Cracks					
General					
Surface Cracks	F	P	G	G	N
Deep Surface Cracks	G	G	G	G	F
Internal Cracks	N	G	N	N	F
Internal Voids	N	f	N	N	G
Welds					
Slag Inclusions and Porosity	N	F	N	P	G
Surface Cracks	G	P	G	G	P
Internal Cracks, Lack of Fusion and Penetration	N	G	P	N	G

Legend: G-Good F-Fair/Marginal P-Poor N-Not Suitable

1.2 References for NDT of Structural Steel

American Society for Metals, Metals handbook. Non-destructive inspection and quality control. ASM, Metals Park, OH 12

American Welding Society, Guide for the non-destructive inspection of welds. ANSI/AWS B.1.10-86, AWS, Miami, FL.

American Welding Society, Structural welding code steel, ANSI/AWS D1.1-90, AWS, Miami, FL

ASTM Designation: E94 Standard guide for radiographic testing. 1990 Annual book of ASTM standards, vol. 03.03, ASTM, 1989.

ASTM Designation: E1032 Standard method of radiographic examination of weldments. 1990 Annual book of ASTM standards, vol 03.03, ASTM, 1985.

FWHA Ultrasonic testing inspection, Federal Highway Administration, Washington, DC.

Section 2 - Wood

2.1 Methods of Detection of Defects in Wood Components

Wood components develop decay from many causes outlined in Part 1, Section 2, Material Defects, of this manual. There is potential for decay which results from the reaction between wood and iron giving rise to loose connections not adequately covered.

Methods for detecting deterioration in wood described herein are separated into two groups; namely, those which identify exterior or surface deterioration, and those which are used to assess deterioration in the body of the wood.

There is no single tool or method that can accurately determine the extent and severity of deterioration. Of the methods discussed, none can satisfactorily identify all defects, and each has its limitations. Usually, the information derived by using a number of simple tools (figure 2.1) and methods together can provide a relatively accurate assessment of the extent of defects and deterioration in wood.

Figure 2.1 Typical tools used for testing wood condition. Left to Right: pick, hammer, probe, coring tool, boring tool and treated wood plugs.

2.2 Methods for Detection of Surface Deterioration

2.2.1 Probing

Probing with a pointed tool, such as a knife, awl or screw driver, can locate decay near the surface of the wood. Decay is indicated by excessive softness and lack of resistance to penetration of the probe. Although the actual procedure is simple, experience is required to distinguish decay from water-softened wood which is otherwise sound. In addition, pressure treated wood may be sound on the surface but rotted beyond the treated layer.

Advantages

- Simple and quick procedure.

Disadvantages

- Some soft species, such as cedar, may be particularly difficult to assess using this method;
- Interpretation of results subject to experience of investigator;
- May not detect interior decay.

2.2.2 Pick test

In this test, a pointed pick, screwdriver or awl is driven a short distance into the wood, transverse to the grain, to pry out a sliver of wood from near the edge of a component. Sound wood has a fibrous structure and pries out as long splinters, while decayed wood breaks abruptly and crumbles into small pieces (figure 2.2.2).

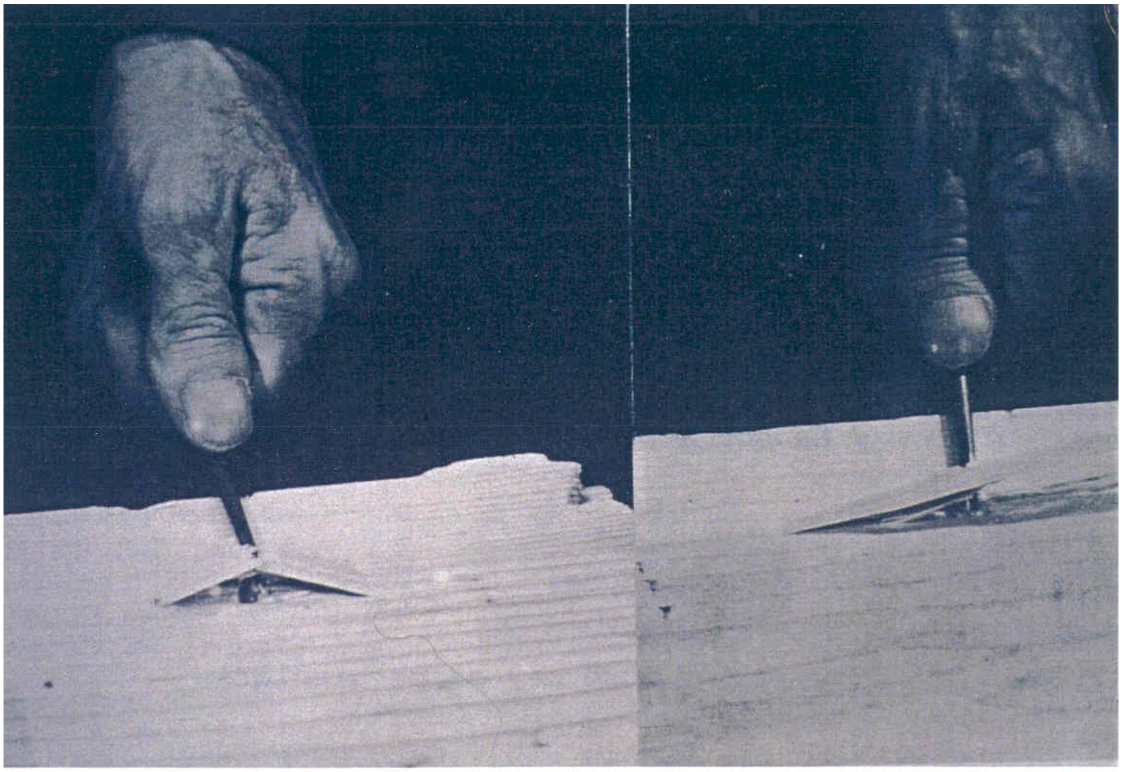

Figure 2.2.2 Pick test: The picture on the left hand side illustrates decayed wood while the one on the right shows sound wood with no decay

Advantages

- Simple and quick procedure

Disadvantages

- A large sliver of wood has to be removed for each test and leaves local damage to the treated surface. <u>This must be repaired;</u>
- May not detect internal decay.

2.2.3 Pilodyn

A pilodyn (figure 2.2.3) is a spring-loaded pin device that drives a hardened steel pin into the wood. The depth of pin penetration is used as a measure of the degree of decay.

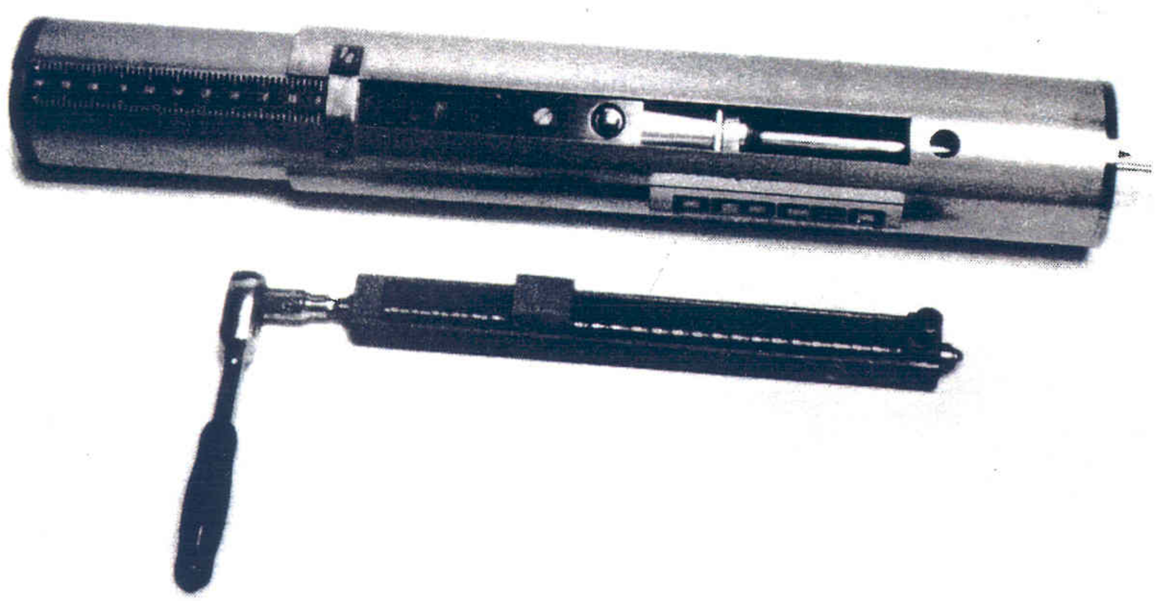

Figure 2.2.3 Typical Pilodyn used for assessing wood condition.

Advantages

- Can provide a relatively accurate calibrated/quantitative assessment of depth of decay;
- Simple and easy to use.

Disadvantages

- Equipment has to be calibrated, and results have to be corrected for moisture content and wood species;
- May not detect internal decay

2.3 Methods for Detection of Interior Deterioration

2.3.1 General

Interior deterioration is more difficult to locate because there may be no visible evidence on the surface of the component. Several methods that can be useful in identifying probable decay are described. With each of these, the existence and extent of the problem should be confirmed and defined with core samples.

2.3.2 Sounding

Sounding is a commonly used method and involves striking the surface of the component with a hammer, or other similar object, and assessing the resulting tonal quality. A dull or hollow sound may indicate the presence of internal voids due to decay (figure 2.3.2). However, other factors may be present which may make clear identification difficult.

Figure 2.3.2 Simple use of a hammer to sound a wood timber. Decay is indicated by a hollow sound.

Advantages

- Quick and simple to apply;
- Can readily identify very severe deterioration.

Disadvantages

- Results are subject to interpretation by inspector;
- Cannot detect wood in incipient or intermediate stages of decay
- Cannot determine the extent of decay. Suspect decay must be verified by other methods such as boring and coring.

2.3.3 Moisture Meter

A moisture meter measures the electrical resistance of the wood between two metal pins which are driven into the surface (figure 2.3.3a). The resistance measured is then correlated to the moisture content in the wood. A centre probe between the pins indicates the depth of penetration of the pins. The pins are removable and available in various lengths for determining moisture contents to depths up to 75mm into the wood. The holes left by the pins can be repaired by treating with preservative.

A measure of the moisture in wood will provide an indication of conditions that are conducive for decay. Moisture contents in excess of about 30% indicate conditions suitable for decay. If the measurements are carried out after a severe or prolonged period of dry weather, then moisture levels of 20 to 25 percent may be cause for concern.

An alternative instrument to check for moisture is a shigometer. The shigometer uses a pulsed current to measure changes in electrical conductivity associated with wood decay. A small hole is drilled into the wood (figure 2.3.3b) and a probe is inserted into the hole (figure 2.3.3c). The probe measures zones or regions of decreased resistance. If the readings drop 50% to 75% to that of sound wood, the region is drilled and cored to determine the extent and nature of the decay.

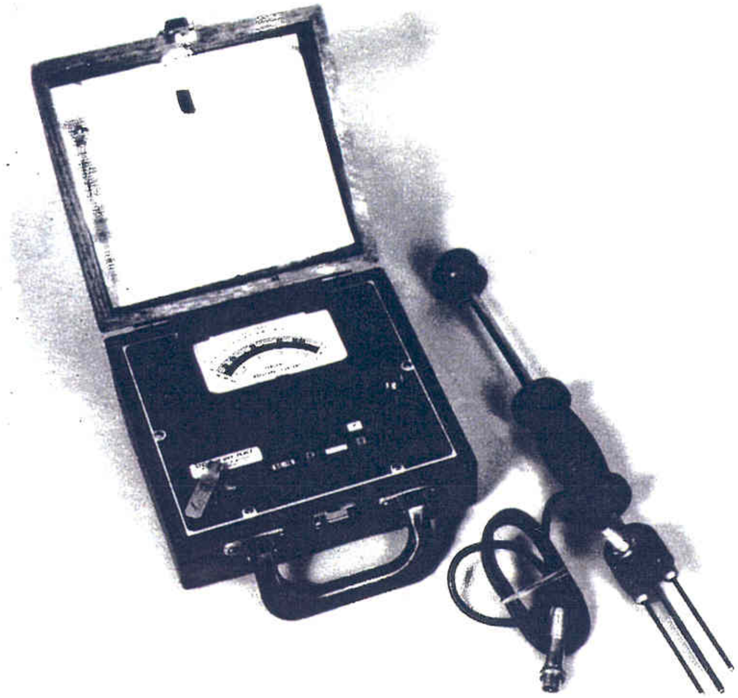

Figure 2.3.3a Typical resistance-type moisture meter.

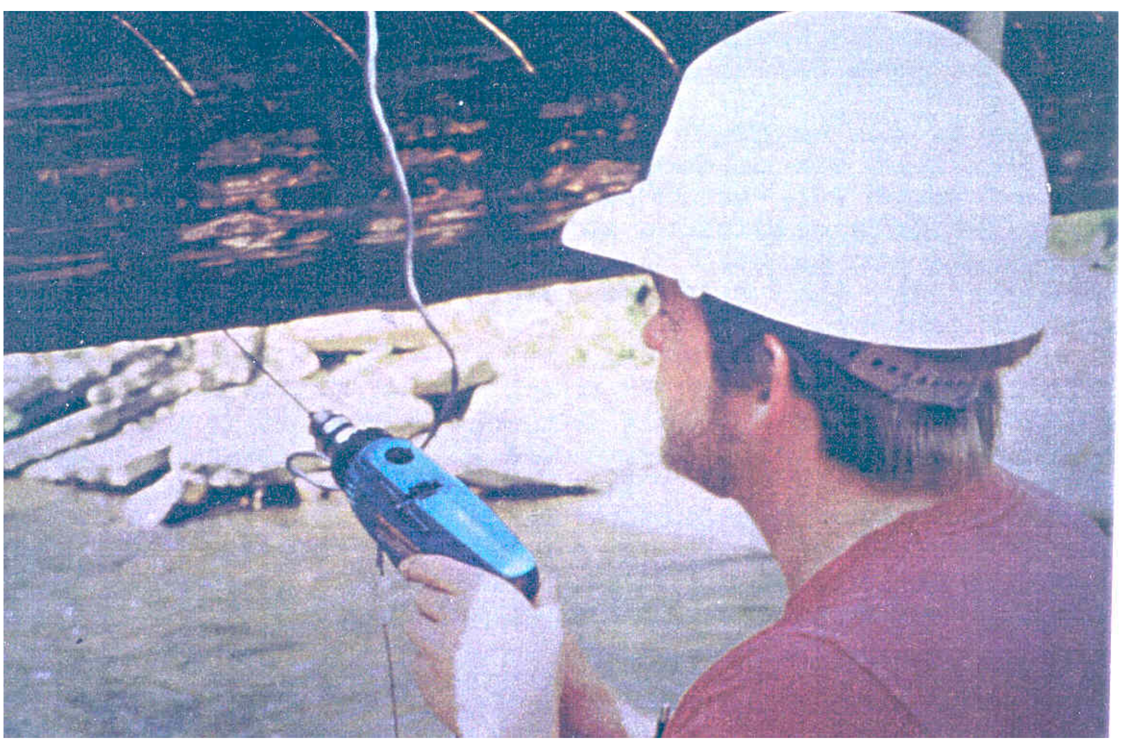

Figure 2.3.3b Drilling of the wood beam in preparation for the shigometer probe.

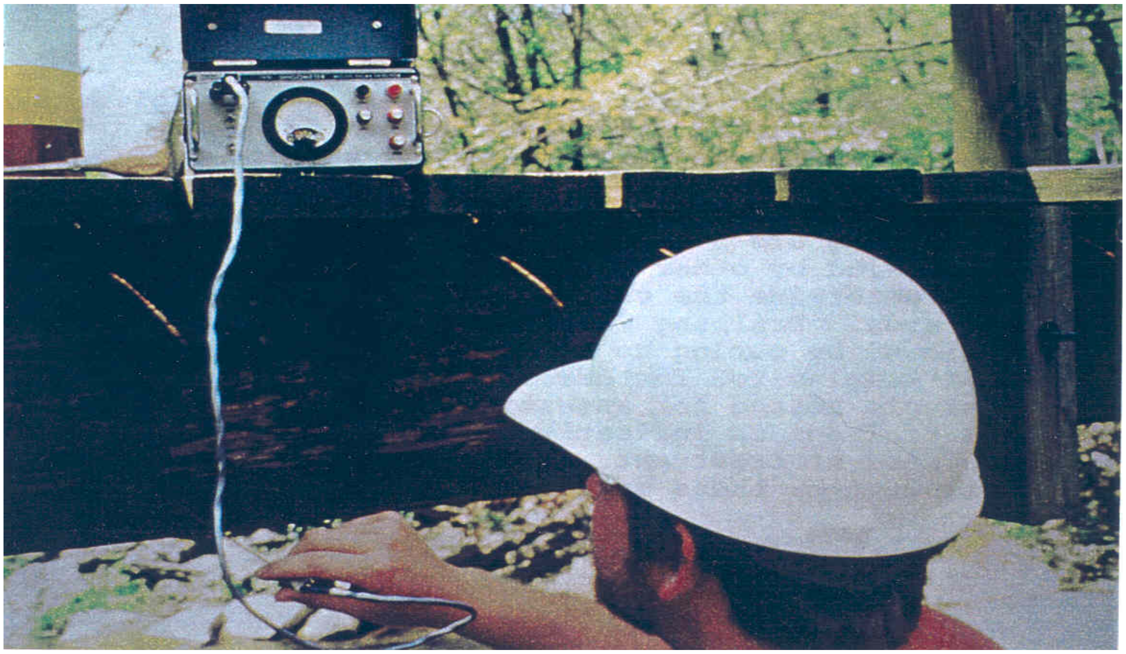

Figure 2.3.3c Application of the shigometer probe.

Advantages

- Highly portable and easy to use;
- Can determine areas where decay is suspect or possible.

Disadvantages

- Does not directly detect decay;
- Must be calibrated and corrected for temperature conditions;
- Suspect areas must be evaluated by core sampling.
- Small holes left by the pins, potential areas for wood decay

2.3.4 Drilling and Coring

Drilling and coring are the most positive means to confirm the presence of internal voids and decay, and to determine the thickness of the remaining sound material.

In drilling, a hand drill with a 10mm to 20mm diameter bit is used to drill a hole into the wood. Zones or pockets of decay and deterioration are noted by ease of drilling and by examination of wood shavings. Although power drills may be faster, a hand drill is more suitable, giving the inspector better control and feel in detecting soft pockets.

Coring with an Increment Borer produces a length of solid core from the wood which can be directly examined for decay and tested. The equipment used for coring and extraction of a wood core is shown in figures 2.3.4a to figure 2.3.4c.

Drilling and coring are generally used to confirm suspect areas of decay identified by other methods (sounding, moisture meter etc.), and to determine the extent or limits of decay, in terms of depth and area. Drilling is often used to establish evidence of decay followed by coring to define the limits of decay and extraction of samples for further laboratory analysis. Culturing provides a simple method for assessing potential risk of decay. The presence of fungi is indicative of wood in an early stage of decay and in need of treatment.

Drill bits and borers must be sharp. Dull tools will break, crush and splinter the wood making interpretation of samples and results difficult.

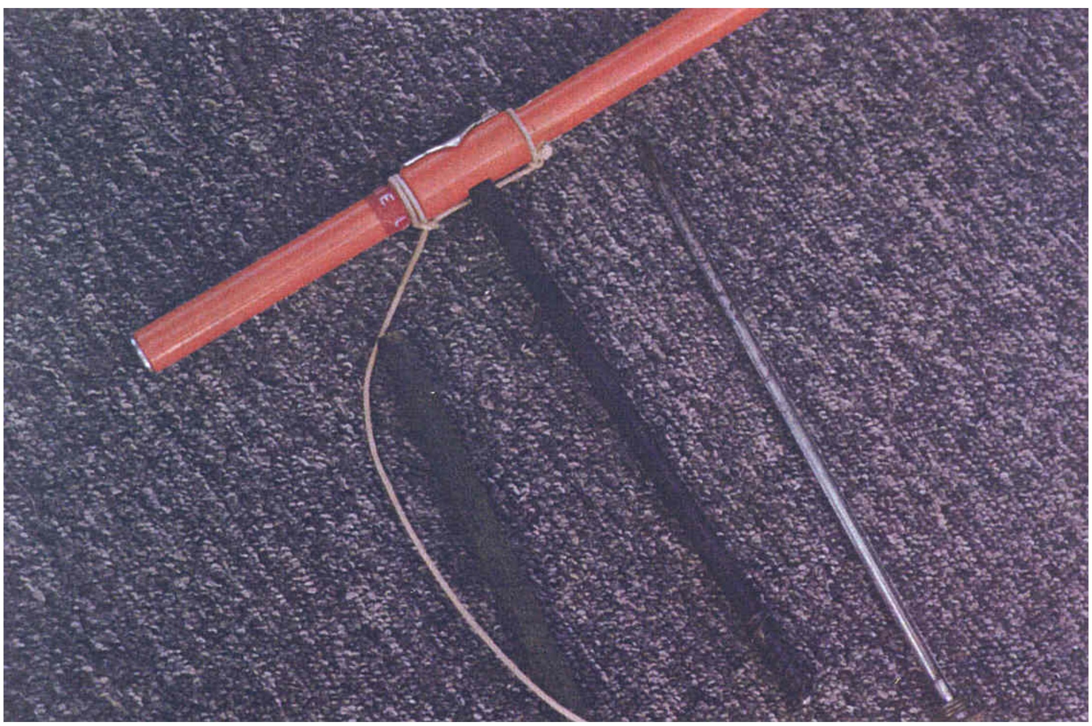

Figure 2.3.4a Equipment used for boring and coring. The piece of pressure treated wood is used as a plug to repair damage done by boring.

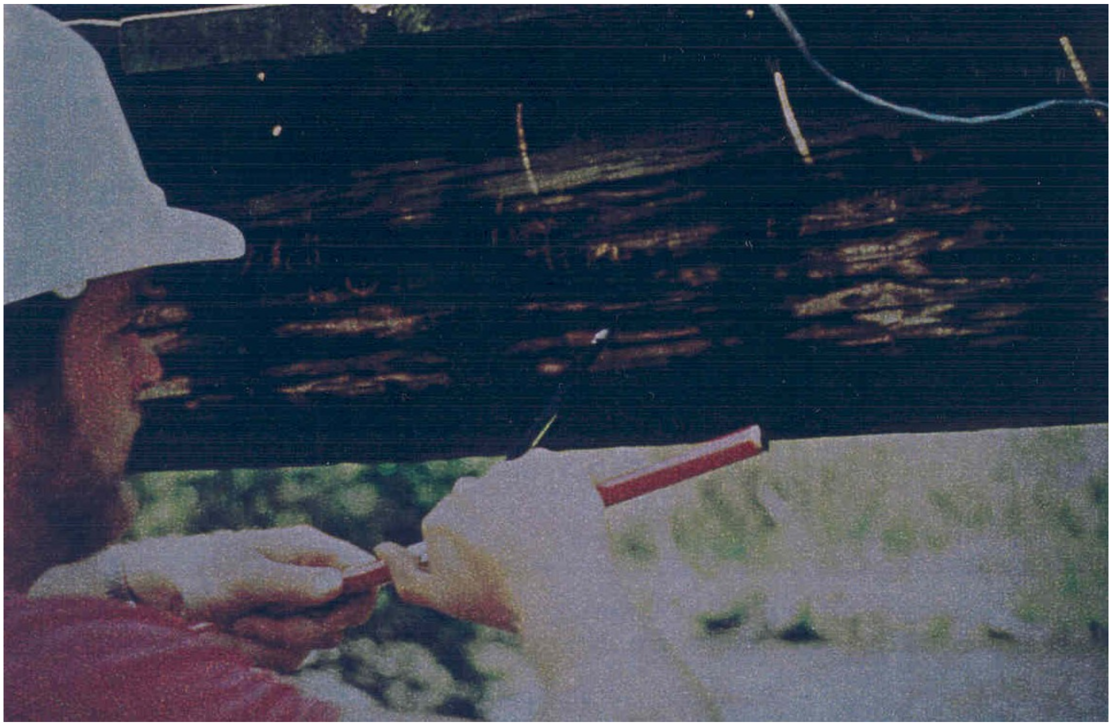

Figure 2.3.4b Simple application of the boring tool.

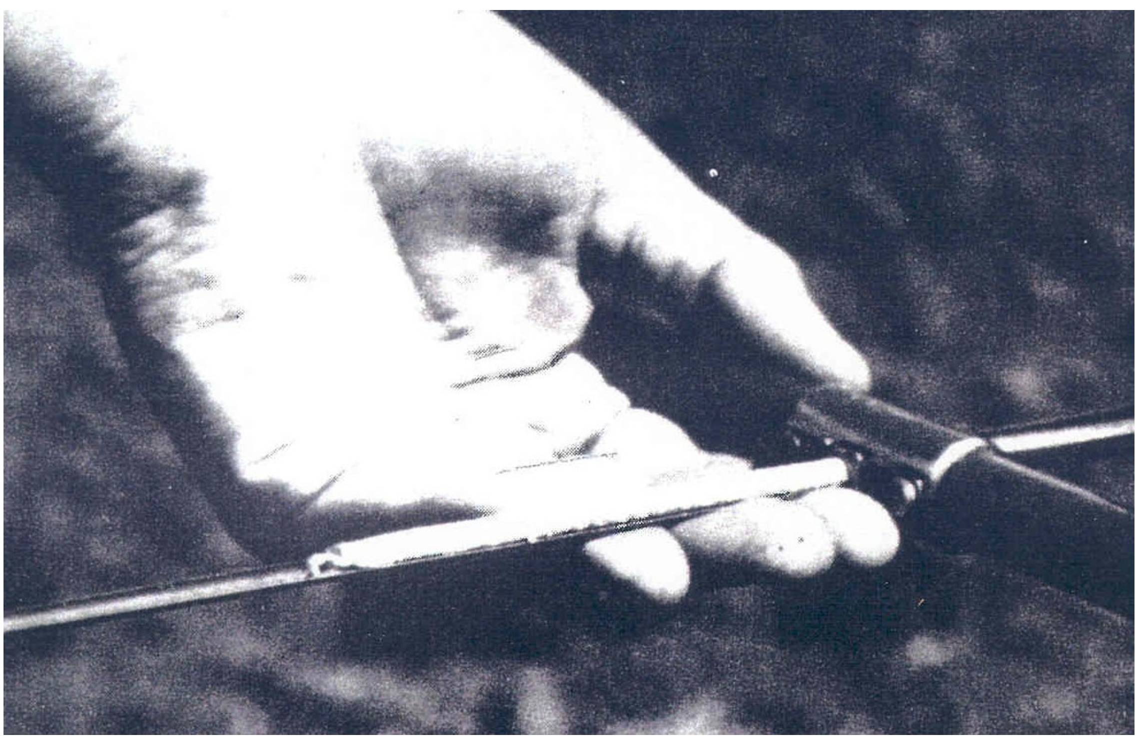

Figure 2.3.4c Wood core removed by an increment borer.

Advantages

- Relatively simple and portable tools involved;
- Drilling provides a rapid initial assessment of interior deterioration;
- Coring produces a sample which can be further analyzed in detail in the laboratory;
- The core can be used to determine the depth and extent of existing preservative treatment and sound wood;
- The inspection hole is useful for the insertion of a shell depth indicator, to obtain further data.

Disadvantages

- Interpretation of shavings and cores subject to experience of inspector, or must be sent to approved laboratory for analysis;
- The surface treatment is interrupted by the inspection hole which must be treated and plugged.

2.3.5 Shell-Depth Indicator

A shell-depth indicator is a metal bar or rod which is notched or hooked at one end and inscribed with ruled markings along its length (figure 2.3.5a). The hooked end is inserted into the inspection hole and pulled back along the side of the hole. As it is removed, the hook will be easily pulled through voids and decayed areas but will catch on the edges of solid sections (figure 2.3.5b). The inspector can thus determine the depth and extent of decay and remaining solid portions as read from the ruler markings.

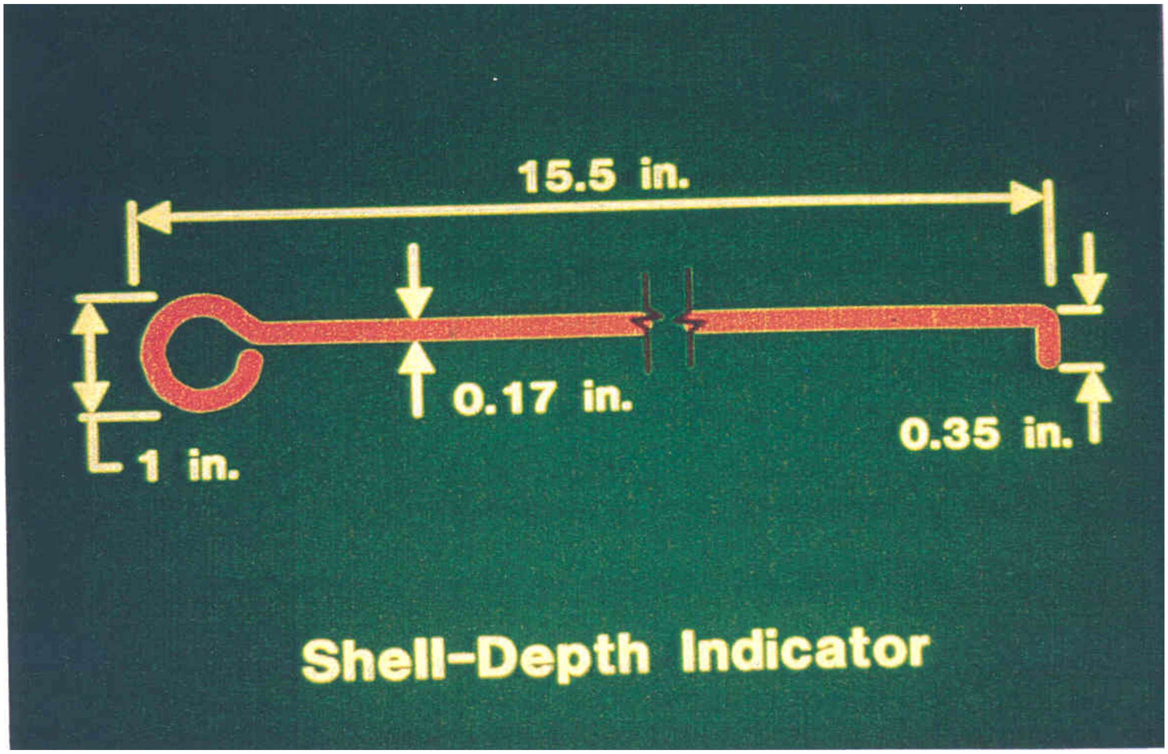

Figure 2.3.5a Schematic of a shell-depth indicator.

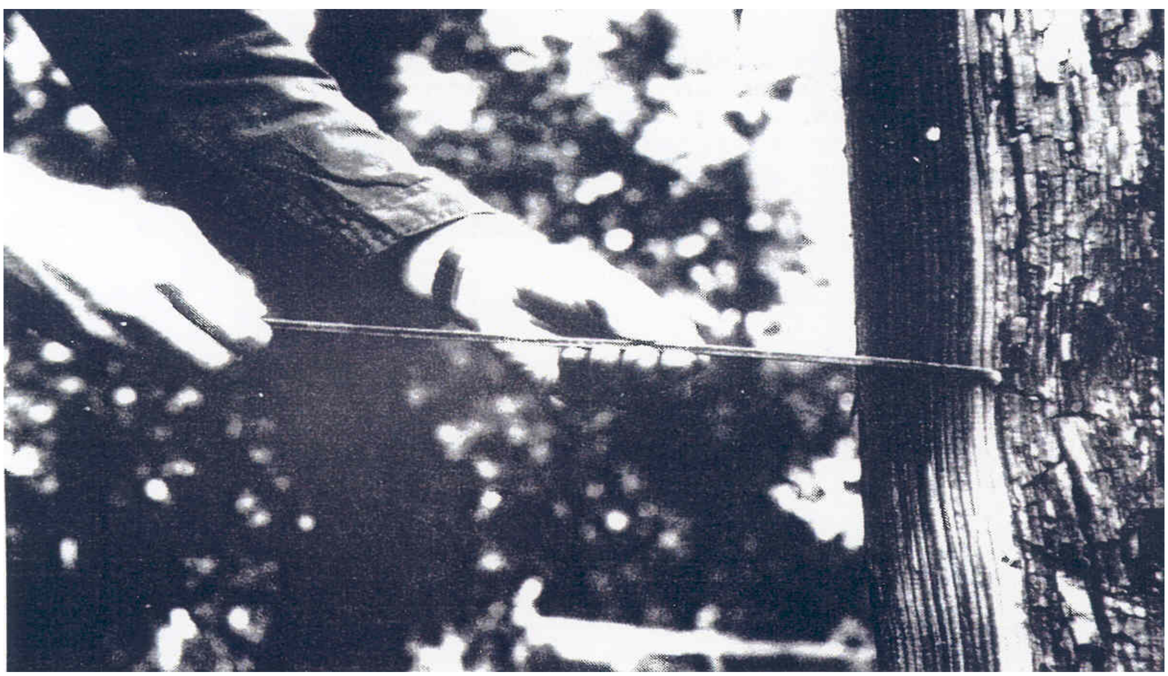

Figure 2.3.5b Use of a shell-depth indicator. Note: The wood member has been partially sectioned to illustrate the application of the indicator.

Advantages

- Highly portable and easy to use;
- Can determine depth of decay
- Can be used to estimate residual strength.

Disadvantages

- Needs to be used in conjunction with drilling or coring;

2.3.6 Sonic Testing

Several methods, including sonic wave velocity, acoustic emission and stress wave analysis have been used for examining wood. These methods typically involve the use of devices which emit and pick up sound waves as they travel over the surface and through the depth of the wood. The variations in the travel time of the sound waves are recorded and can be related to the residual strength of the member. No direct indication of decay is obtained.

The basis for these methods is that the characteristics of a sonic wave are altered in some fashion as it passes through decayed and softer areas. With further development, these methods will offer a significant advancement in the accurate detection of decay and deterioration.

A typical device used for sonic testing is shown in figure 2.3.6

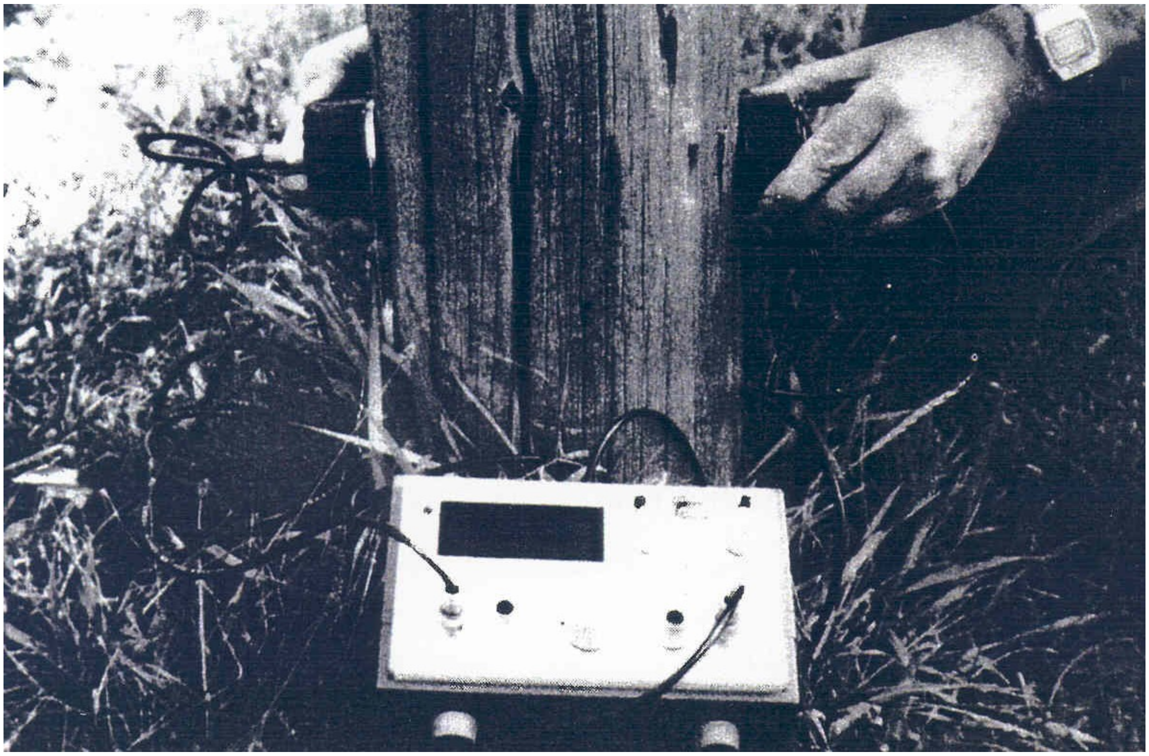

Figure 2.3.6 Typical sonic testing equipment.

Advantages

- Can determine the approximate location and area of deterioration through differential application;
- Portable
- Calibrated to give the residual strength of the component.

Disadvantages

- Still developmental to some extent;
- Cannot be used in the saturated zone at the water line;
- Requires special training in the use of the equipment;
- Core samples must be obtained and analyzed to confirm decay or deterioration and to determine the cause.

2.3.7 Ultrasonic Testing

Ultrasonic testing of timber is similar to sonic testing in that the variations in travel time of sound waves is measured and evaluated to provide an indication of the residual strength of a member. High frequency sound waves are induced into the wood by means of a transducer and picked up by another mounted on the opposite side.

Advantages

- Can determine the approximate location and area of deterioration;
- Can be used to evaluate the saturated zone at the water line;
- Portable

Disadvantages

- Still developmental;
- Requires special training in the use of the equipment and in the interpretation of the observations
- Core samples must be obtained and analyzed to confirm decay or deterioration and to determine the cause.

2.4 Post-Inspection Procedure and Treatment

Several of the inspection methods and tools described involve the removal or destruction of a portion of the wood. These locations, such as at drill and probe holes, will become entry holes for insects and decay. <u>All the surfaces at these locations must be thoroughly treated with an approved preservative following the inspection.</u> Holes should be plugged for their full length with treated wood plugs or dowels, slightly larger in diameter than the hole.

Generally, treatment with creosote or copper naphthenate is sufficient for bridge components.

Failure to carry out a post inspection treatment can result in development or acceleration of decay at inspection locations.

A summary of the methods typically used for detection of defects and deterioration in wood is given in Table 2.4 This table is provided for the purposes of relative comparison of each method, and to assist the user in selecting a suitable method for a particular application.

Table 2.4 **Comparison of Methods for Detecting Deterioration in Wood**

	Surface Deterioration		Internal Deterioration		
Inspection Method	Exterior	Shallow Depth	Voids	Insect Attack	Decay
Probing	G	F	N	N	N
Pick Test	G	F	N	N	N
Pilodyn	G	G	N	N	N
Sounding	N	G	F	P	F
Moisture Meter	G	G	N	P	P
Drilling & Coring	N	N	G	F	G
Shell Depth Indic.	N	N	G	F	G
Sonic	N	N	F	F	F
Ultrasonic	N	N	F	F	F
Radiation	N	N	G	F	G

Legend G - Good F - Fair/Marginal P - Poor N - Not suitable

2.5 References for NDT of Wood

ASCE technical Committee on Wood, Evaluation, maintenance and upgrading of wood structures, A Guide and Commentary. Prepared by the Subcommittee on Evaluation , Maintenance and upgrading of

Timber Structures under Technical Committee on Wood, ASCE, 1982.

Core H.A. and Cote W.A. Wood structure identification. 2nd ed. Syracuse University Press, Syracuse, NY, 1979

JANEY J.R. Guide to investigation of structural failure. Report prepared for ASCE Research Council on Performance of Structures, ASCE, 1986.

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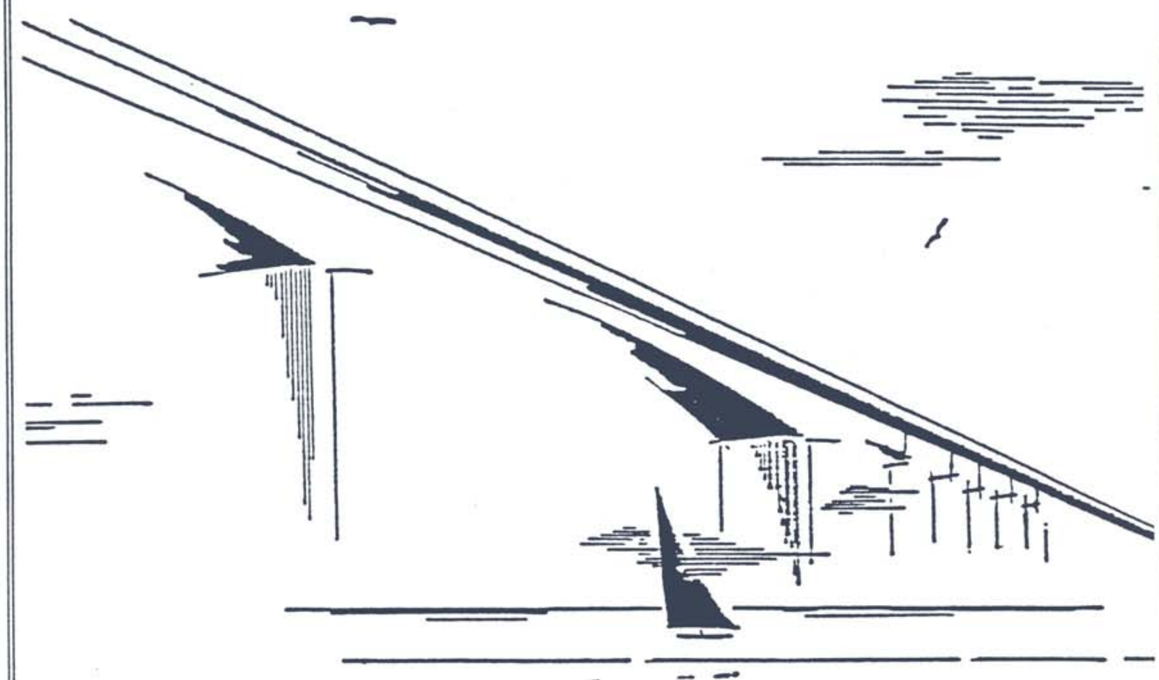

ONTARIO

STRUCTURE INSPECTION MANUAL

Part 5 – Underwater Inspections

PART 5 - UNDERWATER INSPECTIONS

CONTENTS

Section 1 - Inspection of Submerged Components

Contents

1.1 General

A significant number of Ontario bridges are built over waterways with abutment or pier foundations either partly or totally submerged. These components cannot be thoroughly evaluated from the water surface and must be occasionally inspected below to determine their condition and state of deterioration.

The underwater environment, in fresh water, is generally benign to all usual construction materials. Conditions beneath the surface of the water are relatively constant throughout the year and vary insignificantly from year to year. Material which is continuously submerged remains saturated and there is little oxygen available to promote deterioration. The pH of most surface water is close to neutral and temperatures below the surface vary over a narrow range between a minimum of approximately 0° to a maximum of about 20°C.

The rate of deterioration of construction materials continuously submerged in fresh water in general is no greater than in the atmosphere and usually is much less. This does not apply to portions of the structure in the wave zone that are frequently exposed to the most severe conditions of both the water and the atmospheric environment. Conditions encountered here are conducive to rapid deterioration (in spite of the fact that steps are normally taken to mitigate deterioration; concrete is air entrained, steel is painted with protective coatings and timber is pressure treated with a wood preservative) and this area must be carefully inspected. Any deterioration occurring below the water surface will be evident at the water line and this area should be observed during all routine inspections.

Another critical area for all structures founded in water is at the interface with the material underlying the foundation. Here, deterioration of the construction materials is not a significant problem compared to the potential for erosion of the stream bed under and around the foundation.

With respect to the personnel performing an inspection, the underwater environment is hostile. It is cold, particularly when one is submerged for an extended period of time, usually dark and frequently loaded with sediment to the point where no light penetrates.

A wide variety of methods have been developed for underwater inspection. Several of these techniques are described ranging from low water wading, skin diving, and diving with SCUBA or a surface supported air supply. Each method has particular applications and can provide reliable information on the condition of the structure. The use of divers using SCUBA or a surface supply is regulated by the Department of Labour and the "Diving Regulations", O. Reg. 634/86 of the Occupational Health and Safety Act are rigidly enforced.

During any underwater investigation, all structural components are visually inspected, where visibility permits, or examined tactually. Observed conditions are recorded through notes and taped recordings of voice communications between the diver and the surface, underwater photography with a hand held still camera or video or with a remotely operated robot when conditions demand its use. Remote observations can also be made using sonar or ground penetrating radar.

1.2 Safety

Working on or near the water in any capacity involves a great degree of risk and precautions must be taken to ensure the safety of all personnel. The inspection team should be comprised of no less than three persons who are always in visual contact and each must wear a DOT approved personal floatation device. Additional safety procedures which must be followed are identified in Part 2, Section 1.3 of this manual.

Inspection work performed by a diver, whether with SCUBA or a surface air supply, is governed by the "Diving Regulations" under the Occupational Health and Safety Act which require the team to be comprised of at least three persons, the diver, a stand-by diver and a tender. One of them must be identified as the Dive Supervisor who must not enter the water while the work is in progress. In addition, the Regulations clearly identify the minimum equipment requirements as well as safety precautions. Under the Act, the ultimate responsibility for the safety of the workers lies with the employer so it is incumbent upon the owner to ensure that those employed for this work are competent and qualified to carry it out.

1.3 Training and Experience

Visibility beneath the water surface is often restricted and the entire bridge component may not be visible. The overall condition must therefore be pieced together from a series of observations of discrete segments. A meaningful assessment will depend upon the inspectors ability to understand what he sees, or feels, and how it relates to the overall structure and its integrity. The underwater inspector should be knowledgeable in bridge design and construction details and should know where to look for specific problems and common defects. Alternately, a diver lacking this experience must be in direct voice contact with a knowledgeable and experienced inspector on the surface who can direct the investigation and evaluate the observations during the course of the work.

All underwater investigations should be carried out under the direct supervision of a Professional Engineer who can certify the completeness and correctness of the work.

When the inspection is carried out by a diver, all members of the diving team must be fully trained in the use of all diving equipment and devices and in the performance of underwater work.

1.4 Non-Destructive Testing of Underwater Structures

Non-destructive testing techniques similar to those used above water can be applied to quantify any defects identified below the water surface but in each case the equipment and procedures require modification. These techniques are listed again with considerations for underwater use.

1.4.1 Ultrasonic Testing

Ultrasound techniques can be used effectively under water. When used underwater, the transducers must be enclosed in a waterproof housing. The method is used extensively to determine the residual thickness of metal sections when only one surface is exposed or when quick, accurate measurements are required of any component. Because the water provides a sound connection of the transducer and the section being measured, a couplant is not required.

Ultrasonic testing of concrete under ideal conditions is difficult to successfully carry out. This is due to the unique cracking patterns that develop in the material and block the sound waves. The problems encountered are compounded underwater and although it can be used, the results are not always reliable.

When this technique is used for wood inspection the equipment must be calibrated for saturated timber material. Residual strength of the timber can be determined through the application of empirical methods and formulas which are dependent upon the wood species. Relative measurements can be made for a single component by comparing observations from a questionable area to those from at a known sound location within the same member. Care and experience are required to assess the results obtained.

1.4.2 Magnetic Particle Inspection

Magnetic particle testing techniques are also used underwater for cracks or discontinuities in the surface of components. The process is the same as used on the surface except the magnetic particles are in a water suspension of fluorescent dye (figure 1.4.2). The flux leakage at the defect creates an accumulation of the coloured particles indicating location and size. This deposit can be measured and photographed to create a permanent record. The surface still must be cleaned with a wire brush or a water-jet.

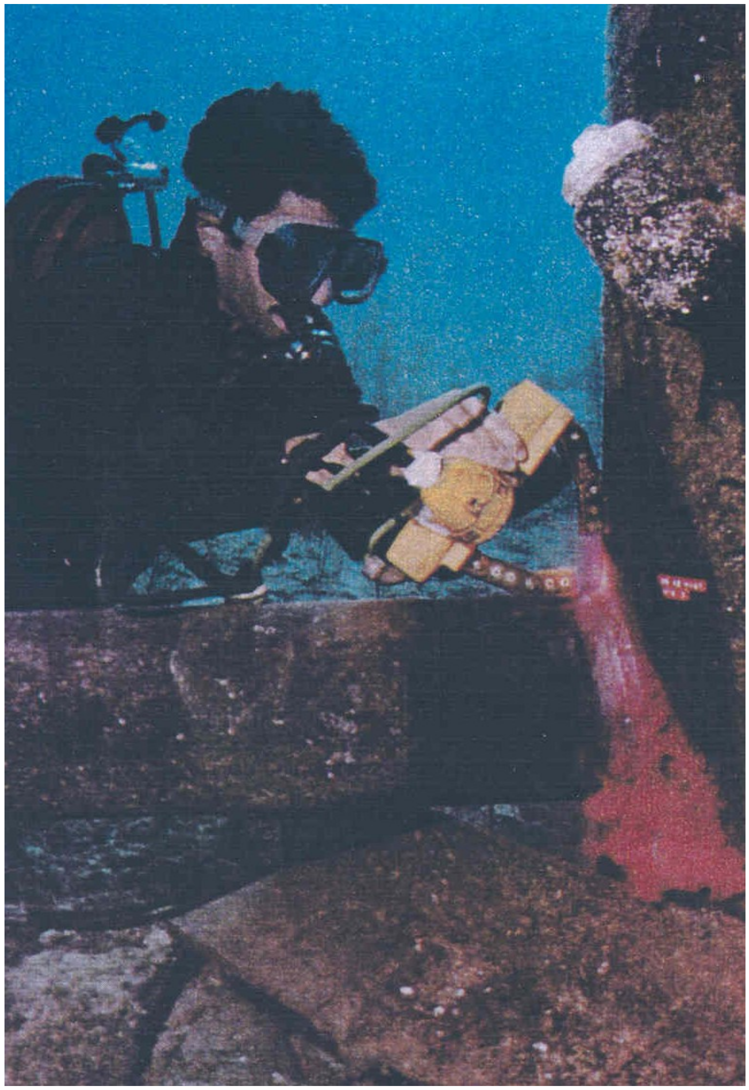

Figure 1.4.2 Underwater Magnetic Particle Inspection.

1.4.3 Eddy Current

Eddy current techniques can be used effectively underwater to locate defects in or near the surface of conductive components, as described in Section 4.1. Ultrasonic methods are then required to quantify the size and extent of noted defects or deficiencies. The method requires a skilled diver who is also a highly trained testing technician to use the equipment and interpret the results. The greatest advantage of this system is that cleaning of the surface is not as critical as with other methods.

1.4.4 Radiography

Radiography is not readily adapted for underwater use and is not normally used in this environment. When conditions require the degree of detail available through the use of this technique, gamma radiation is most readily utilized but all water must be evacuated between the radiating source and the object under test.

1.4.5 Coring

Coring of concrete is partially destructive and consideration must be given to repair of the cavities produced where cores are removed. Cores can be tested in accordance with approved procedures to verify and correlate data obtained by other means. They can be obtained underwater with purposely designed drills or from the surface by drilling vertically downward through the structure.

1.4.6 Sounding

Tonal qualities of sound produced in timber and concrete, underwater, by a hammer are different than those produced above. The difference will be noted when comparing sound wood or concrete to that harbouring significant decay. Sounding may identify the presence of decay and can provide a rapid indication of the extent of significant deterioration.

Section 2 - Equipment and Tools

Contents

2.1 Hand Tools

To effectively carry out an underwater inspection, the diver must have available an assortment of hand tools to facilitate cleaning, chipping, sounding, measuring etc. Many of those used in a Level 1 Inspection for identification of deterioration and quantifying its extent are also utilized in a Level 2 Inspection to determine limits of probable deterioration or deficiencies, and for quantifying size, location, distribution and severity. Where samples of material are required, power tools may be needed for cutting or coring. Extensive problems may require two or more divers in the water at the same time who must be in direct voice contact with each other

A variety of equipment is required for underwater inspection purposes and this can include almost all hand tools normally used during a structural inspection of any structure above water. Those most commonly employed underwater are illustrated in figure 2.1.

Figure 2.1 Typical Hand Tools for Underwater Inspection

2.2 Power Tools

Work of any nature underwater is physically demanding and where excessive effort is needed to achieve results, power tools should be considered. These can include high pressure pumps where extensive cleaning is required, and pneumatic and hydraulic power tools such as saws and drills. The latter must be purposely designed to avoid environmental contamination.

2.3 Photography

In all instances where deterioration or defects are identified they should be recorded photographically if at all possible. The diving inspector should be equipped with an underwater camera or a land camera in a water-tight housing. To record small details like cracks in structural members or pits due to corrosion, a close-up lens is required. A "clear-water" prism is to be used where visibility is reduced due to sediment or suspended solids.

Underwater video systems provide another means for recording observations. These must be produced with a real time commentary by the diver describing what is being recorded. In addition, a referencing system must be used to graphically identify the location on the structure of what is being viewed on the screen.

Remotely operated vehicles equipped with a video camera provide a means for the inspector to visually inspect the submerged portions of a structure without putting a diver in the water. The equipment must be used with some form of grid system to monitor the location. All observations must be interpreted immediately by the inspector and recorded on the tape as it is produced.

2.4 Notes and Observations

The most practical means for recording observations made underwater by a diver is to record voice communications during the inspection on tape. In addition, the diver should be equipped with some means to produce sketches, while submerged, that will illustrate the observations.

Section 3 - Frequency of Inspection

Contents

3.1 Routine Inspections

The inspection of the critical area at the water line is a part of the Routine Visual Detailed Inspections which will identify the need for a more thorough underwater inspection of the submerged portions of the structure.

Conditions at each structure vary considerably and the requirement for regularly scheduled underwater inspections cannot be generalized. All structures with submerged components should be inspected below the water surface at least once. This should be undertaken as soon after original construction as possible to facilitate early remedial action to rectify any construction defects or deficiencies.

The need for additional underwater inspections will be identified at the time of the initial inspection if potential problems are identified, or through the routine bridge inspection program.

Whenever an underwater inspection is warranted the minimum level of effort should be a Level 1 Visual Inspection due to the relatively high cost of mobilizing a dive team to the bridge site. Such an inspection of the entire structure can be carried out relatively quickly in the presence of minimum deficiencies and will ensure that any defects are identified and documented.

Concrete structures will experience little in the way of deterioration below the critical zone at the water line. Once the structural element in this region has been determined adequate it need not be inspected again until other major rehabilitation is required. Such structures on bedrock foundations may never need another underwater inspection.

Structures on soil foundations will require regularly scheduled underwater inspections to evaluate the stability of the stream bed adjacent to structural components and as part of this assessment a Level 1 Inspection of the structure can be incorporated. The timing of these inspections will be dependent upon the foundation material and its susceptibility to erosion. For structures in good repair, in a non-aggressive environment and on stable foundations these inspections can be scheduled at 10 year intervals. Where the stream bed is more prone to erosion the interval should be reduced to 5 years. Where stream bed erosion is a significant problem some other means should be devised to monitor it.

Zebra mussel infestations are creating unusual problems for structures where they are established. As they grow and multiply an anaerobic environment is created at the surface of the substrate which is conducive to the development of sulphur compounds. These result in microbial induced corrosion of steel components which can be considerably more aggressive than normal oxidation. The impact of the resulting sulphates on a concrete substrate is known to exist but is yet to be evaluated. Where these creatures are established, particularly on steel components, monitoring on a yearly basis will be required in order to quantify the resulting deterioration. Their complete removal should be attempted only if all exposed surfaces are to be given a protective coating to isolate them from further infestation and to inhibit galvanic corrosion.

3.2 Non-Routine Inspections

Non-routine underwater inspections will be required as a result of an unusual event such as after impact by a vessel, exceptional ice conditions or accumulations of debris or where there is evidence of foundation movement. At locations with scour prone stream beds, an underwater inspection should be carried out after any exceptional flood event. This will normally be a Level 1 Inspection and will identify the need for a more thorough assessment.

Section 4 - Inspection Procedures

Contents

4.1 Existing Data

Before an underwater inspection is carried out, the Inspector should review the as-built or construction drawings of the structure, details of any restoration or rehabilitation work carried out on the submerged portions and all previous inspection reports in order to monitor the progress of known defects or deterioration.

4.2 Wading

Where the water depth is relatively shallow (less than about a metre), the river bottom is reasonably hard and there is little or no current, the submerged components can be inspected during the regular routine inspections with the inspector wearing chest waders and a personal floatation device. The critical area for observations is at and immediately below the water line, and this can be readily inspected while wading. In clear water, observation below the surface can be made with the use of a simple viewing tube as illustrated in Figure 4.2 or with a conventional face mask. Where visibility below the surface is limited, the critical area can be examined tactually. During a wading inspection, the condition of the stream bed adjacent to the structure can also be evaluated.

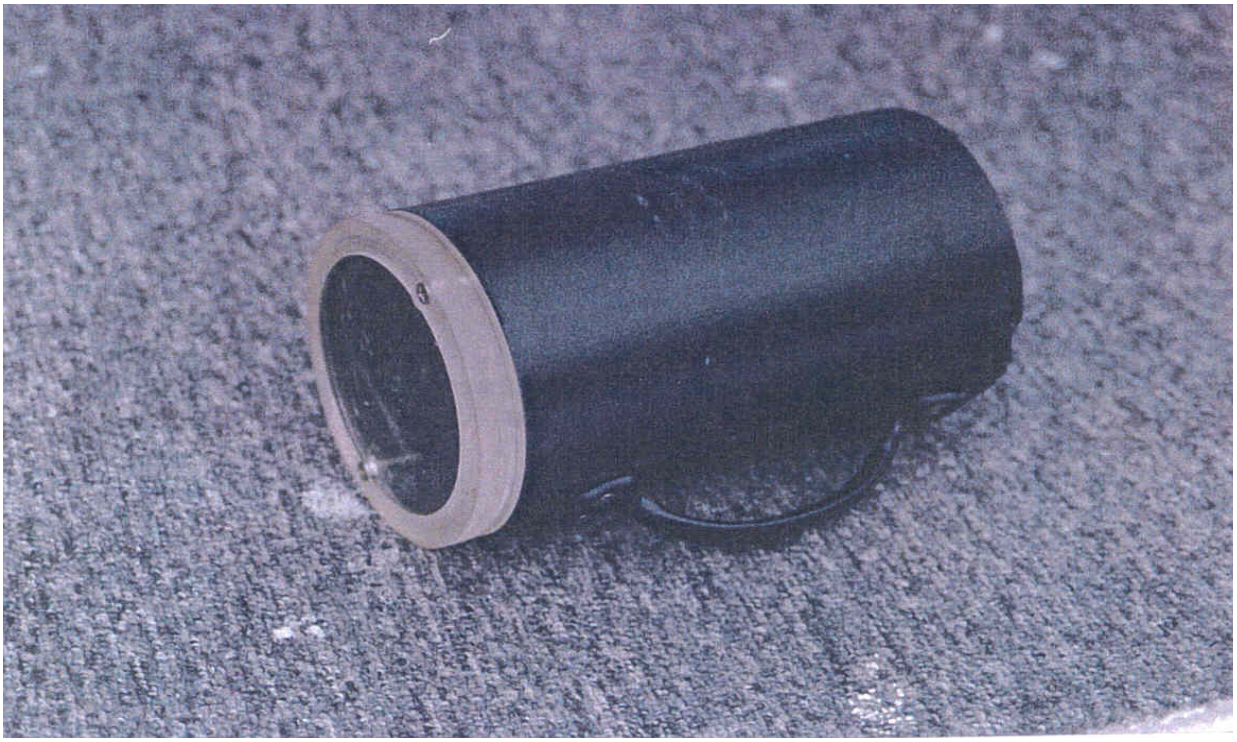

Figure 4.2 Underwater Viewing Tube

4.3 Skin Diving

An underwater visual inspection in shallow, clear water may be carried out from the surface by an inspector who is competent and comfortable when skin diving with a face mask, swim fins and a snorkel. The critical area at the surface will be clearly visible as should the stream bed at the base of the foundation.

Although skin diving is not regulated by the Ministry of Labour, it must be carried out in a manner that will not jeopardise the safety of the diver. The skin diver must be tethered to a float on the surface or to another member of the inspection team on shore or in a boat.

4.4 Deep Diving

Where the depth is more than about a metre, particularly where there is limited visibility, most underwater inspections will be carried out by a diver equipped with SCUBA or a surface air supply. With this equipment there are few limitations. The diver can work at any depth encountered at bridges in Ontario and under all conditions of flow and visibility.

Underwater inspections can be carried out most readily using SCUBA due to its convenience and mobility but under some circumstances a surface air supply will be essential for a thorough examination of the submerged portions of a structure. The type of equipment needed for the specific site must be identified through a Site Reconnaissance Survey by the Diving Supervisor before commencing the inspection to determine water depths, flow conditions, unusual potential hazards, underwater visibility, special tool or inspection procedure requirements, etc.

Section 5 - Levels of Inspection

Contents

5.1 Levels of Inspection

With all structures in the fresh water of Ontario, deterioration of underwater components is generally going to occur at and just below the water surface and at the interface with the soil. The most severe deterioration of all materials will be in the wave zone where they are exposed to the deleterious affects of both the water and the atmospheric environment. Erosion of the stream bed and undermining of the structure is the greatest concern at the bottom. Between these two locations, little if any significant problems due to deterioration will develop except possibly in acidic streams. This may result in deterioration of all submerged components and dictate the need to assess all exposed surfaces.

One exception is masonry structures which can experience the softening and loss of mortar from all the joints in the exposed surfaces.

Another is structures infested with zebra mussels. These animals are found in the continuously submerged zone below that affected by seasonal conditions such as exposure, wave action and abrasion from ice and debris.

When an underwater inspection is to be performed the initial approach will be a visual inspection using simple, non-destructive testing techniques. This should identify and describe any deficiencies in sufficient detail for a structural evaluation of the problem and form the basis for any further detailed inspection. The level of detail required will dictate the procedures and equipment to be used.

5.2 Level 1 - Visual Inspection

A Level 1 Inspection will provide a visual or tactile examination of the exposed underwater surfaces of a structure in sufficient detail to detect major damage or deterioration and to confirm the continuity of all structural elements. It will provide a general assessment of the condition of the submerged components and will identify the need for a more detailed inspection.

At the surface, abrasion resulting from floating ice and debris will usually provide a clean surface for observations. Below the wave zone, representative areas at known locations for potential problems such as welds, pile interlocks, connections and connectors may require cleaning with a scraper and a wire brush to remove algae or other aquatic growths in order to expose the substrate.
Concrete and timber structures can be sounded with a hammer to provide a qualitative assessment of the materials beneath the surface. In the wave zone, timbers are to be <u>carefully</u> probed for indications of internal decay.

The interface between the structure and the stream bed will be examined for indications of active or incipient erosion. Where there is active erosion, characteristic depressions will be observed at the upstream face of the bridge piers and abutments. Where the stream bed is in a state of dynamic stability, material being brought into the site over a period of time is essentially equal to that being carried away, probing of the bottom with a steel rod to evaluate the relative density of the stream bed material may indicate the depth of active scour under flood flow conditions. Any observed signs of erosion are to be noted and measured.

Structural deficiencies will be apparent in the exposed portions of the structure. The extent of any such defects should be traced below the water surface.

Any observed defects or deficiencies are to be noted as to size and location. Significant structural defects are to be measured and photographed in sufficient detail to facilitate a preliminary structural assessment to evaluate their impact on the safety and integrity of the structure. This assessment will confirm the need for a Level 2 Inspection.

Where excessive corrosion is found or suspected, macro photos of the cleaned surface are required for evaluation and future comparisons.

5.3 Level 2 - Detailed Inspection

A Level 2 Inspection is a highly detailed inspection of critical structural elements where extensive repairs or possible replacement is anticipated. It will be carried out in response to the structural evaluation of deficiencies identified by a Level 1 Inspection or to investigate obvious underwater deterioration or defects manifested in the structure above the surface. This will usually entail extensive cleaning of the structural elements to remove all algae and bio-fouling, obtaining detailed measurements and photographs and possibly non-destructive testing of apparent defects or of critical components. Sampling of materials for analysis and testing may also be required. These procedures will be at identified defective areas or at locations which are representative of the critical submerged portions of the structure. The specific procedures to be used will be dependent upon the type of material and its position in the structure.

5.3.1 Detailed Inspection of Steel Structures

The detailed inspection of steel structures will be directed primarily toward the joints and fasteners with particular attention being given to welds and the adjacent heat affected zones and known stress raisers. Cleaning of the components will be carried out with a wire brush or a water-jet to expose bare metal for a careful and thorough visual examination. Where defects are identified or suspected the area can be further examined using non-destructive evaluation techniques such as ultrasound, magnetic particle or eddy current as described in Section 4.1 of this manual and below.

The extent of corrosion will be noted and where it appears to be excessive, the residual thickness of the material should be measured. Mechanical fasteners will be examined for corrosion and tested for tightness.

Where the structure is comprised of standard rolled sections measurements of representative elements can be obtained using conventional measuring devices once the exposed surfaces have been cleaned. Flanges of "H" piles can be measured using an outside calliper, vernier calliper or a micrometer. Where it is necessary to determine the web thickness a modified calliper as illustrated in figure 5.3.1a may be used in conjunction with a vernier calliper.

Members with only one exposed surface such as pipe piles or sheet piles can be measured using ultrasound. Discreet pits in the surface of the component should be measured for depth using a pit gauge, figure 5.3.1b. The density of the pitting should be recorded photographically.

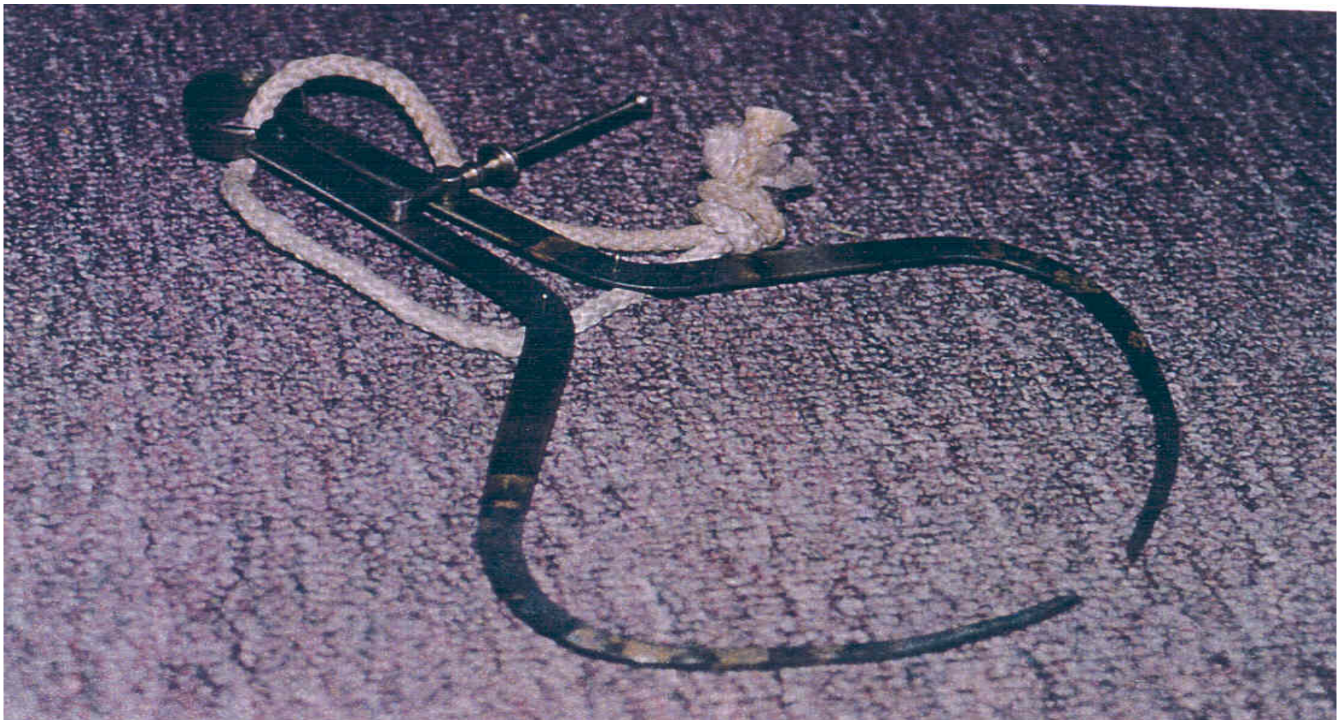

Figure 5.3.1a Modified calliper for thickness measurements.

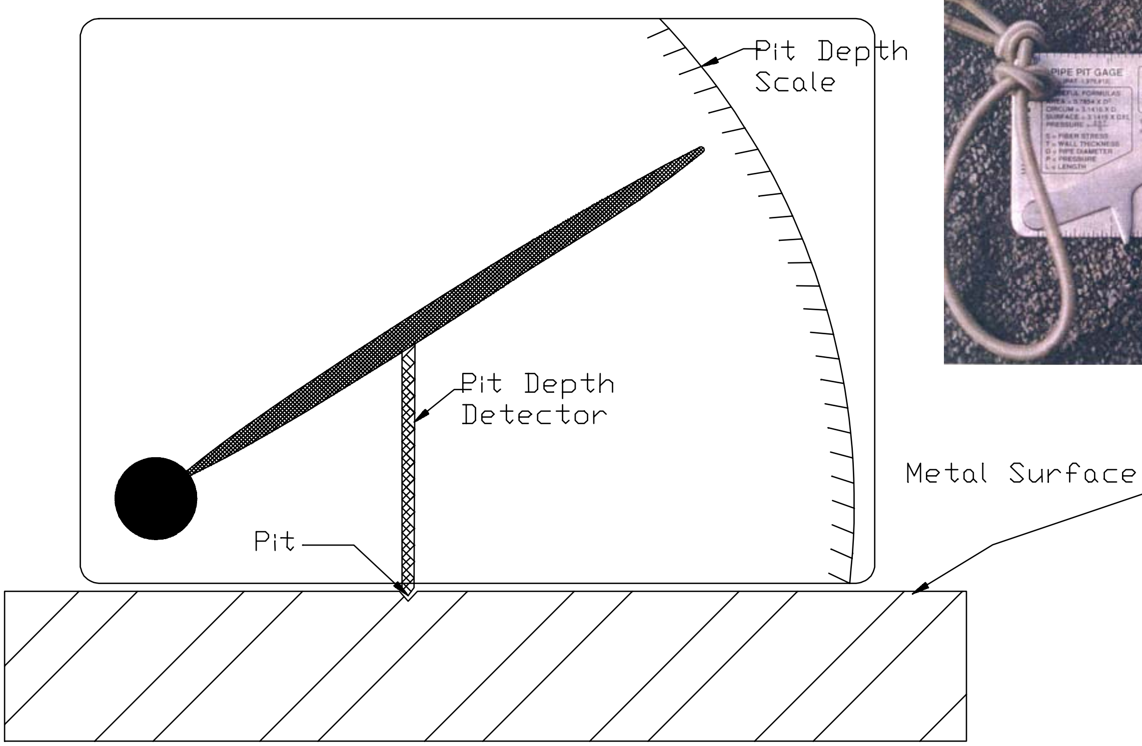

Figure 5.3.1b Pit Gauge.

5.3.2 Detailed Inspection of Concrete Structures

Deterioration of concrete due to exposure in fresh water is normally insignificant and a detailed inspection will be primarily to define construction defects or physical damage. This will entail a very careful visual examination with photographs of observed problems and some non-destructive evaluation techniques to define the area of concern. Several of the standard non-destructive and destructive testing procedures and equipment used to collect data on concrete components above water can be modified for use underwater.

Where general deterioration of the concrete surfaces is occurring due to high or low pH of the water, the condition will be apparent near the surface where specific tests can be carried out.

5.3.3 Masonry

The joint pattern in masonry structures materially limits the use of non-destructive testing procedures. A qualitative assessment of the mortar joints can be made using a chisel or screw driver and the masonry components can be sounded with a hammer.

To quantify any observations requires core drilling vertically downward because of the extreme care required to recover even the best mortar in the joints.

5.3.4 Wood

The standard non-destructive and destructive testing procedures and equipment used to collect data on wood components above water, as detailed in Section 4.2 can be used directly or modified for use underwater.

Section 6 - Scour Investigations

Contents

6.1 Scour Investigations

Bridge components in or adjacent to streams need to be investigated to determine if the bridge is scour critical. A scour critical bridge is one with abutment or pier foundations which are unstable due to scouring of the stream bed or which potentially may become unstable due to scour. This assessment will be based on a geotechnical evaluation of the site, the hydrology of the tributary drainage basin with respect to observed floods and potential floods and the hydraulics of the watercourse considering the reaches upstream and downstream of the structure as well as the water passages through it.

Each bridge should be rated on its propensity for damage due to scour based on:

* Hydraulic capacity relative to the flood potential of the tributary basin;

* Water velocity through the structure under "bank full" condition and the design flood;

* Erodibility of the stream bed;

* Stability of the watercourse, does it have a tendency to meander;

Based on soil types and the water velocity through the bridge opening the following scour potential ratings should be applied.

Stream bed Material	Bank Full Velocity	Rating
Granular and Silt	<1 m/s 1-2 m/s >2 m/s	5 3-4 2
Clay/Till	<2 m/s 2-3 m/s >3 m/s	5 4 3
Shale Limestone Granite	> 3m/s >5 m/s	4 4 6

A rating of 6 indicates scour will never be a significant problem whereas a rating of 3 or less indicates the need for further investigations and possible protective measures. In addition to the foregoing scour rating, each structure must be rated based on the potential for collapse or severe damage as a result of scour and its impact on the travelling public.

6.2 Inspection Procedures for Scour

6.2.1 Probing

Where the erosion potential of a bridge site is great (rated 3 or lower) the stream bed may be in a state of dynamic stability with a continuous bed load moving through the site. Under these conditions there can be very significant erosion during a flood but as the flow diminishes the stream bed is re-established at or close to its original condition. Where this condition is suspected, the stream bed must be carefully evaluated by probing or through various geotechnical techniques that can produce a sub-bottom profile of undisturbed soil.

6.2.2 Diver Inspections

A visual examination of the stream bed by a diver will indicate if active erosion is occurring and will identify exposed piles or the underside of spread footings. Where the stream bed is in a state of dynamic stability and infilling of erosion features has occurred, probing of the bottom adjacent to abutments and piers may reveal loose sediments as well as the depth to sound material.

6.2.3 Sounding

The stream bed, both upstream and downstream of the structure and within the water passages should be sounded where any potential exists for scour. Sounding is best obtained by using a recording type echo sounder with particular attention being given immediately adjacent to the abutments and piers. The position of all observations should be related to the centre line of the bridge. Where the scour rating is 3 or lower, the stream bed should be re-sounded after every spring freshet and all other significant flood events. If the stream bed stabilizes at an elevation that does not threaten the stability of the structure the soundings can be scheduled at five year intervals and after any major flood event.

The area of concern should extend approximately 30m upstream and downstream from the face of the bridge.

A narrow beam transducer (5^{0} or less), operating at a frequency of 200kHz or more will produce a reasonably accurate indication of the bottom profile. A wider angle will result in more extraneous signals due to reflections off the vertical surface and will be more difficult to interpret.

A scanning type sonar with a rotating head can also be used to trace down the face of a pier and across the stream bed, identifying any cavities beneath the foundation.

Sonar equipment is reasonably portable and can generally be mounted in or on any type of boat. The results are graphically recorded on a strip chart as a permanent record and these are easily interpreted. Weed growth on the bottom will affect the accuracy of observations and air in the water will materially affect the signal, sometimes obscuring it completely.

6.2.4 Sub-Bottom Profiler

A sub-bottom profile can frequently be obtained using sonar operating in the range of 50kHz or less. Such equipment will obtain reasonable penetration of the loose sediments on the bottom but with some loss of detail.

The equipment is similar in every respect to conventional sonar although some expertise is required for interpretation of the data.

6.2.5 Ground Penetrating Radar

Ground penetrating radar is a relatively new procedure for geotechnical investigations and its applications are being rapidly expanded. It is well suited to sub-bottom profiling from a boat, or from surface ice. Its greatest advantage over sonar is that the signal is not affected by entrained air.

The equipment is considerably more bulky than sonar and considerable expertise is required for computer enhancement of the recorded data and for the interpretation of the results.

6.3 Corrective Actions

If the scour investigations and assessment indicate that the stability of a structure is jeopardised, then appropriate actions should be taken to mitigate the problem. This will usually be in the form of armour stone or rip-rap placed on the stream bed in close proximity to the bridge components.

Any proposed method of control will require a hydraulic analysis of the watercourse downstream of the structure and through the bridge openings to determine its impact on the capacity of the water passages and on the stability of the stream bed beyond the protection.