TRACK AND CIVIL INFRASTRUCTURE

CODE OF PRACTICE

VOLUME THREE - TRAM SYSTEM [CP3]

STRUCTURES

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1.0 PURPOSE AND SCOPE

1.1 PURPOSE

The purpose of this part is to set standards to ensure that:

a) structures built to support the tramline (e.g. underbridges) are safe and fit for purpose;

b) structures built beside or over the tramline are safe and fit for purpose;

c) structures owned by others on, or adjacent to, the tramline right-of-way comply with the relevant standards and are sound, of safe construction and maintained in safe condition;

d) proper procedures are in place to inspect structures, detect any deterioration of condition, assess any remedial action required and ensure the safety of trams (with the necessary temporary measures) before repairs are carried out .

1.2 PRINCIPLES

This part complies with the principles set out in the “Code of Practice for the Defined Interstate Rail Network”, volume 4, part 2, section 9.

1.3 SCOPE

1.3.1 Structures included

This part specifies general procedures for the design, rating, construction, monitoring and maintenance of tramline structures. It applies to:

a) existing structures shown in the schedules of section 4;

b) new fixed structures beside, over or under the track, including:
   1) buildings;
   2) footbridges and subways;
   3) tramline and road bridges; culverts;
   4) under-track services;
   5) any other fixed structures in the tramline right-of-way.

1.3.2 Structures not included

This part does not include supports for overhead electric traction equipment, signalling or telecommunications structures, which are the responsibility of other groups within the TransAdelaide organisation.

1.4 REFERENCES

1.4.1 Australian Standards

AS 4799: 2000 Installation of underground utility services and pipelines within railway boundaries

1.4.2 Industry Codes

Australian Bridge Design Code - Published by Austroads Incorporated

Bridge Management Practice - Published by Austroads Incorporated

Code of Practice for the Defined Interstate Rail Network, volume 4 (Track, Civil and Electrical Infrastructure), part 2 (Infrastructure Principles), section 9: Structures

1.4.3 TransAdelaide documents and Infrastructure Services Management System Procedure Manual

QP-IS-501: Document and Data Control
CPRD/PRC/046 Records Management

2.0 DESIGN AND RATING

2.1 MANUALS AND CODES

Design and rating of structures shall be carried out in accordance with the manuals and codes shown in table 2.1:

Table 2.1: Design/rating of structures

Structure	Manual or code
Under track structures	Australian Bridge Design Code
Road bridges	Australian Bridge Design Code
Footbridges	Australian Bridge Design Code
Services	AS 4799: 2000 (Installation of underground utility services and pipelines within railways boundaries)
Other structures	Relevant Australian Standards

2.2 STRUCTURES OWNED BY OTHER PARTIES

2.2.1 Rating by owner

Structures owned by other persons or organisations, and subject to agreements whereby TransAdelaide can require that person or organisation to rate the functional capacity of the structure, shall be so rated and certified.

2.2.2 Action if structure considered unsafe

Where a structure owned by another person or organisation is considered to present an unacceptable risk to the safe passage of trams, TransAdelaide shall:

a) notify the relevant person or organisation in writing requesting appropriate action be taken to reduce the risk to acceptable levels;

b) consider the need to impose operational restrictions or other means to reduce any immediate risk.

2.2.3 Report to appropriate regulatory body

If the risk is not addressed satisfactorily then consideration shall be given to reporting the situation to the appropriate regulatory authority for resolution.

2.3 REGISTER OF STRUCTURES

a) A register providing information on all structures to be inspected should be established and maintained.

b) Major structures such as road and tram bridges should have the location marked on the structure.

3.0 ELECTROLYSIS

3.1 PROTECTION AGAINST ELECTROLYSIS OR CORROSION

Where pipelines are laid within the tramline boundary, protection against electrolysis or corrosion is required by TransAdelaide. At the time of installation or subsequently, such protection shall be provided and maintained by the Owner of the pipeline to the satisfaction of TransAdelaide.

3.2 ELECTRIC TRACTION AREAS

In existing and proposed electrified traction areas, all metallic services and pipelines within the property of TransAdelaide shall be provided with an approved electrical insulating coating or covering in accordance with AS 4799: 2000 (Installation of underground utility services and pipelines within railway boundaries).

4.0 MONITORING AND MAINTENANCE

4.1 INSPECTION, ASSESSMENT AND MAINTENANCE ACTIONS

Inspection, assessment and maintenance actions of structures shall include the specific conditions shown in table 4.1.

Table 4.1: Structures inspections, assessment and maintenance actions

Type of inspection or action	Specific conditions or actions to observe
Scheduled inspections	
Walking inspections	a) Identify visually, and report, obvious structure defects and conditions (i.e. indicators of a defect) that may affect, or indicate problems with the integrity of structures including the following: 1) changes in the alignment of the structure (e.g. as indicated by track geometry error or movement in vertical or horizontal alignment; 2) component or structural member damage, e.g. as caused by derailment, collision, dragging equipment on rolling stock or vandalism; 3) other obvious defects that may affect the structure's integrity. b) Intervals between walking inspections shall not exceed 31 days.
General inspections	a) Identify and report structure condition and significant changes in condition since the previous inspection. General inspections should be assisted by the use of devices to enhance the use of the naked eye (eg. binoculars) where required. b) A general inspection should be carried out when suspected defects are identified from conditions determined during walking inspections. c) Further guidelines for general inspection of bridge structures and reporting are detailed in Appendix 1. d) General inspections should include the tasks of the walking inspection and in addition look for conditions or changes in the conditions, which may affect the function of the structure including the following: 1) defects or changes in the structural integrity of components; 2) any component damage caused by derailment, collision, dragging equipment on rolling stock or vandalism; 3) undermining of footings or foundations; 4) unusual discolouration; 5) unusual seepage of water; 6) crushing of components. e) For each structure inspected the following should also be carried out: 1) re-inspection of previously reported defects that require monitoring as determined from previous inspections; 2) inspection of known defect types common to the particular structure form and material; 3) site testing and measurement where required. f) Scheduled general inspections shall be at intervals not greater than those defined in table 4.2, column 2.

Table 4.1*(continued)*: Structures inspections, assessment and maintenance actions

Type of inspection or action	Specific conditions or actions to observe
Scheduled inspections *(continued)*	
Detailed inspections	a) Detailed inspection of a structure shall investigate all aspects of its condition and behaviour. b) Scheduled detailed inspections shall be at intervals not greater than those defined in table 4.2, column 3.
Unscheduled inspections	To be undertaken following a defined event or the report of a damaged structure.
Assessment, method of assessment, maintenance actions and response	The integrity of structures shall be assessed to verify their capacity to safely perform the required function. Where changes to the configuration or condition of the structure has been identified, an appropriate capacity assessment shall be made to determine required actions. Where the condition of the structure is assessed as constituting a potential risk, appropriate action shall be taken to ensure the immediate safety of operations. Follow up action shall then be taken to ensure the structure is restored in accordance with the requirements of section 2.

4.2 INTERVALS FOR GENERAL AND DETAILED INSPECTIONS

The intervals between general and detailed inspections shall be as shown in table 4.2:

Table 4.2: Intervals for general and detailed inspections

Item	Interval	
	General inspections	Detailed inspections
Under & over track structures		
- timber components	1 year	3 years
- steel components	2 years	6 years
- concrete components	2 years	6 years
- masonry components	2 years	6 years
- underwater components	see note	6 years
- underground untreated timber	see note	4 years
- underground treated timber	see note	8 years
Other Structures	See note	

Note: Inspections shall be at intervals appropriate to each structure dependent on condition, age, structural capacity and other environmental factors and operating conditions.

5.0 DOCUMENTATION

5.1 SCHEDULES OF BRIDGES

Records shall be maintained of all bridges on the TransAdelaide tramline (including the load rating which shall be determined and recorded) in accordance with QP-IS-501 (Document and Data Control).

SCHEDULES TO BE PREPARED

5.2 SCHEDULES OF STRUCTURES

Records shall be maintained of all structures (except bridges, see sub-section 4.1) on the TransAdelaide tramline in accordance with QP-IS-501 (Document and Data Control).

5.3 INSPECTION REPORTS

All inspection reports shall be maintained in accordance with CPRD/PRC/046 Records Management.

A1.0 APPENDIX 1: GUIDELINES FOR GENERAL AND DETAILED BRIDGE INSPECTIONS

A1.1 INSPECTION REPORTS

Inspection reports shall contain some or all of the following:

a) clear, concise, accurate written statements summarising the condition of each element of the structure describing defects;

b) sketches detailing the nature and extent of significant defects;

c) photographs showing the general structure and all significant defects;

d) recommended rehabilitation measures, and set priorities with target dates for completion;

A1.2 GENERAL INSPECTIONS

The following items shall be checked on bridges:

a) barrier rails for damage;

b) track top and alignment over the bridge;

c) bridge drainage for accumulations of debris on the deck, in gutters and scuppers which may obstruct free drainage and cause ponding;

d) deck joints for loose, missing or damaged bolts and components, free movement and proper functioning;

e) deck, girders, piers, abutments, braces and abutment sheeting and wing walls, for looseness and major damage such as cracking, splitting, distortion, fire and excessive movement or obvious defects such as spalling, cracking, staining, dampness, corrosion and excessive vibration;

f) timber members for termite activity, rotting, marine borer and other insect attack;

g) iron and steel elements for noticeable build up of deposits of aggressive salts, dirt, silt, debris and bird droppings;

h) masonry elements for growth in joints between blocks;

i) propping for tightness of wedges;

j) cathodic protection systems to ensure correct functioning;

k) bearing sills and substructure drains for accumulations of debris which may obstruct free drainage and cause ponding;

l) weep holes in abutments and retaining walls for free drainage;

m) embankments for erosion and scour;

n) batter protection for damage and undermining by scour;

o) waterway under the bridge for accumulations of debris, vegetation growth, silting and scour.

A1.3 DETAILED INSPECTIONS

Detailed inspections shall include all of the items under General Inspections plus the requirements under Section 3.8 of the Austroads Bridge Management Practice 1991.

A1.4 BRIDGE NOMENCLATURE AND CLASSIFICATION SYSTEM

Table A1 introduces the elements of bridge nomenclature and classification, together with their respective abbreviations, which will be defined in this appendix.

Table A1: Elements of bridge nomenclature and classification

Deck Type	Tram / Road Location	Structure Type
Transom-Topped *(TT)*	Deck girder *(D)*	Rolled Steel Girder *(RG)*
Ballasted *(B)*	Through girder *(T)*	Plate Girder *(PG)*
Slab deck *(S)*		Truss *(Tr)*
		Concrete Beam *(CB)*

For example, a bridge with transom track support, with the track located on the top of the girders of the bridge, and whose girders are of rolled-steel construction, would have an abbreviated bridge classification *TTDRG*.

A1.5 DEFINITIONS

The following terms shall be used in reporting the condition of bridges or culverts:

Note: A **bridge** is a structure used to carry a track or road over a waterway, road or track and normally consists of supporting sub-structures such as abutments and piers, on which rest the super-structure, which can consist of girders, trusses, ballasted deck etc. In arch bridges the abutments are well below track level and the supporting structure needs a further supporting medium between the load carrying structure and the tramline. A **culvert** is used to carry a track or road over a waterway or drain and usually refers to an under-track structure consisting of a pipe, precast box or a similar in situ built structure including small arches. Sometimes minor bridges of less than 2m total length are also referred to as culverts.

A1.5.1 Deck Types

a) **Transom** is the term normally used for the timbers spanning between girders or stringers. The running rails are placed directly on the transoms.

b) **Transom-topped structures** have the running rails carried by timber transoms that are supported directly by the steel girders or stringers. These are referred to as **fixed level bridges** because the track level is not adjustable as it is in the case of ballasted track. These structures have also been referred to as **open-decked bridges**.

c) **Ballasted-deck structures** have a slab or trough capable of holding ballast in conventional track construction. Concrete is commonly used in more recent structures. In older structures, the deck is often formed by buckle plates or pressed steel trough units.

d) **Slab-deck structures** are ones in which the superstructure is a concrete slab spanning directly on to the substructure (e.g. Goodwood rail overpass).

e) **Deck girder structures** may be of **open decked** type or **ballasted deck** type. In either case, the timbers or the deck slab are carried directly on the top flanges of the main girders.

f) **Through girder structures** may be of **open decked** type or **ballasted deck** type. In either case, the timbers or the deck slab are carried on **longitudinal stringers**, which, in turn, are supported by **floor beams**. The floor beams are then usually supported near the bottom edge of the main girder. Through girder construction is usually adopted if the depth of the structure has to be kept as low as possible.

g) **Stringers** are longitudinal beams that span between transverse floor beams in through girder bridges. **Side beams** are similar to stringers as they span longitudinally between floor beams, but these only occur at the sides of ballasted decks.

h) **Floor beams** occur in through deck type bridges. They span transversely between the main girders and carry either stringers or some other form of longitudinally spanning structure (for example a concrete ballast trough).

A1.5.2 **Structure Type**

a) **Girders** are the main spanning beams of bridges and culverts. They may be rolled steel beams, rivetted or welded plate girders, reinforced concrete beams or steel trusses. Rolled steel beams may sometimes be referred to more specifically as BSB (British Standard Beam), BFB (Broad Flange Beam), UB (Universal Beam) or some other designation depending on the manufacturer of the beams. **Trusses** may be referred to more specifically as Pratt trusses, Warren trusses or Bow-string trusses according to their configuration of members.

b) **Rolled Steel Girders** are one-piece, manufactured beams that have a top flange, a bottom flange and a web, which is the vertical part of the section between the flanges. Sometimes, the flanges may be increased in size by the addition of one or more plates known as cover plates.

c) **Plate Girders** are of similar configuration to Rolled Steel Girders but are composed of a number of plates and angle fastened together either by rivets or welds. Long rivetted plate girders often have other additional plates referred to as **splice plates** when **flange plates** or **cover plates** need to be joined. Plate Girders were used when the size of beam required was not available as a rolled steel product.

d) **Truss structures** have a top chord, which is analogous to the top flange of a beam, a bottom chord, which is analogous to the bottom flange and web members, which are analogous to the web part of a beam. The **web members** of a truss are a mixture of vertical and/or diagonal members connected to the chords at what are called **panel points** or **nodes**.

e) **Concrete beam bridges** are those with primary spanning members in the form of concrete beams or girders. The beams may be in the form of separate members supporting secondary members or may be placed side-by-side and touching so that they fulfill the function of deck members as well as primary spanning members. In cross-section, the beams may be rectangular with depth greater than or less than width or may be **T-beams** or **I-beams**.

A1.5.3 **Other Bridge Structural Elements**

a) The **superstructure** is the part of the structure above the bearings and is the spanning part of the structure.

b) The **substructure** is the part of the structure below the superstructure. It includes abutments and piers and their foundations.

c) The **abutment** is essentially the end support of a bridge span. In most tramline structures the abutment retains the earth embankment and therefore carries horizontal loads from the earth in addition to the vertical loads from the span. Some are **spill-through abutments** and these carry span loads only. Another type of abutment is the **sill type** of abutment which is a shallow abutment carrying very little retained earth loads and being placed at the top of the embankment or cutting. Sill type abutments are more commonly found in road-over-tram bridges. Concrete is the most common abutment material and may or may not be reinforced. Older structures are likely to have **stone masonry** abutments. Sometimes, **steel sheet piling** or **reinforced earth facing panels** are used to retain the earth and the span is supported independently on a sill type of abutment. (For example, the modern structure carrying the standard gauge main over the River Torrens adjacent to the North Line and Outer Harbor Line bridges in the West Parklands has sill type abutments on reinforced earth).

d) **Wingwalls** are retaining walls adjoining abutments. They carry horizontal loads from the soil they retain.

e) A **pier** is an intermediate support of a multiple-span bridge or culvert.

f) **Span** describes the portion of a structure that spans between piers and or abutments. The main members of spans are generally girders or slabs.

g) **Waterway** describes a bridge or culvert opening containing all or part of a water course spanned by the structure.

h) **Transom bolts** are used to fasten transoms to the longitudinal girders or stringers. Sometimes they are conventional bolts passing through the transom and the top flange of the steel supporting member. In that form they may have a **tapered washer** to match the taper of the flange of a rolled steel girder. An alternative type uses special **cast steel clips** to clamp the transom on to the supporting steelwork.

   Differing schools of thought place transom bolts with head up or down. If the head is up and the nut comes off then the transom is still held against horizontal movement (provided the bolt passes through the flange of the girder) however the missing nut is not easily detected. If the head is down the bolt usually falls out, making inspection easy but leaving the transom completely unfastened.

i) A **deck plate** is a steel plate forming a ballasted deck. Common types of deck plates are buckle plates and deck trough units.

   i) **Buckle plates** are thin sagging steel plates that carry the ballast of a steel ballasted deck. They may sag in one or two directions. They are supported on a combination of stringers, side beams and floor beams. Buckle plates are normally found in older steel structures (for example Outer Harbor line bridge over the River Torrens).

   ii) **Deck trough** units are pressed steel units, which span between the main girders in some forms of ballasted-deck bridges.

j) **Bracing** is a system of transverse and diagonal members attached to beams or columns and preventing them from sideways movement. Attachment may be by welding or by bolting to **bracing cleats**.

Sometimes bracing is provided in structures to directly carry loads applied to the structure. Usually these are horizontal loads such as those due to nosing loads from trams or loads due to wind. Otherwise, the function of bracing is to prevent buckling in members or parts of members in compression. Bracing members are very often made from steel angle section.

k) The **soffit** is the underside of a beam or slab.

l) **Running rails** are those traversed by the wheels of trams on the structure.

m) **Guard rails** are additional rails, usually placed at about 300mm inside the running rails, and are intended to prevent derailed wheel-sets from leaving or impacting a bridge structure.

n) In bridges and culverts, **bearings** are the means of transferring the loads from superstructure elements into the sub-structure. Bearings come in many forms. Small structures may have no more than a steel plate to spread the load over a large enough area to keep stresses low enough for the concrete or stone of the substructure.

Often, the bearings at one end of a span will be designed to allow longitudinal movement of the super-structure as will occur due to temperature changes. In small structures movement is often by sliding of steel on steel with elongated holes where holding-down bolts pass through the members. More modern structures may have pads of **teflon** or similar materials to facilitate sliding. In large structures there may be **special rollers** to allow movement. Another relatively modern form is the so-called **elastomeric bearing** in which movement is accommodated in rubber in a sandwich of layers of steel and rubber.

At both ends of a span there is usually a need to permit some rotation of the ends of the span. In simple structures the edge of the bearing plate forms a pivot. In larger structures the bearings will include a large steel pin forming a pivot between an upper and lower half of a bearing.

o) **Weephole** - Earth retaining walls, including wingwalls and abutments, are often provided with drainage holes near the base of the wall. These are weep-holes and are designed to let water escape from behind the wall thereby preventing a build-up of excessive pressure behind the wall.

p) **Scuppers** are drainage holes provided in bridge or culvert decks.

q) **Batter** - The sloping earth surface formed when a cutting or embankment is constructed is referred to as a batter. The slope is usually expressed as 1 in X (for example, 1 in 1.5) where X is the horizontally measured distance for a unit length of vertical rise.

r) **Ballast walls** are found at the sides of ballasted decks or at the backs of abutments for open-deck structures. They are intended to retain the ballast on ballasted decks or prevent spillage of ballast from behind abutments of open-deck structures.

A1.5.4 Culvert Classification System

a) In **rail-deck culverts** the superstructure consists of used rail, forming a ballast trough. Rails are laid toe to toe, directly on the substructure. Additional inverted rails are nested into the main layer of rails as necessary to achieve the required strength. Further rails are used to form a wall on each side to retain a sufficient depth of ballast.

b) **Pipe Culvert** - The simplest form of under-track structure is the pipe culvert. Headwalls are used unless a pipe of adequate length is used.

c) **Arch Culverts** are similar to pipe culverts. They are usually concrete but can be brick or stone. **Headwalls** are usually provided.

d) **Box Culverts** are usually of reinforced concrete and are usually pre-cast. They are sometimes supplied in one piece (for example many of the pedestrian subways use completely closed pre-cast boxes), but more commonly are supplied as an inverted U-shape on a separate base which may in turn be pre-cast or cast in-situ.

A1.5.5 **Other Culvert Structural Elements**

a) **Headwalls** are found at the ends of pipe, arch and box culverts. They often have integral wingwalls splayed at about 45 degrees to the culvert centreline. The alternative to having a headwall is to extend the culvert length so that it clears the toe of the bank.

b) **Crown** - Concrete box culverts are usually made with a separate base slab supporting an inverted U-shaped piece referred to as the crown unit.

A1.6 DEFECT TYPES

The following terms and descriptions shall be used in describing the different defects or modes of failure in structures:

a) **Blocked** - This is a common defect in small diameter pipes. Partially blocked pipes may or may not be a concern. If a pipe has been installed low relative to the normal bed level of a watercourse then it is likely to be silted to a level similar to the bed level. Pipes such as these together with some others that could have up to 60% of their area blocked by silt are almost certainly going to clear when a significant flow occurs. There is no point in listing these for cleaning out however, if the remaining opening is too small then self cleaning may not occur and steps would be required to clean out all or some of the silt.

More serious can blockage occur when **vegetation** grows or **debris** is caught in the pipe or around the entrance to a pipe. Such defects should be recorded as “vegetation” or “debris” and should be listed for cleaning out.

b) **Broken** - This is self explanatory. It is most likely to occur with steel bracing members, minor concrete elements such as ballast walls or small wingwalls, and timber transoms

c) **Buckled** - This means that a member is distorted in a way that could be due to the onset of buckling failure. Buckling failure occurs in thin or slender members in compression. In the case of slender columns (members subjected to compression from loads in line with members), the whole member may buckle. Alternatively, in members subject to bending or compression or shear there may be local buckling where thin plates buckle due to localised compression stress.

d) **Buried** - This defect description may refer to a pipe in which case the pipe will need to be uncovered and cleaned out unless it can be shown that the pipe is no longer required.

Sometimes, the bearings of a bridge may become covered with ballast, soil or other debris. This prevents inspection of the bearings and should be rectified to enable inspection to be made and also to reduce the potential for corrosion of the buried steel components.

e) **Corroded** - Corrosion is generally found in steel members, particularly in crevices and pockets which can retain debris and water. The bottoms of stiffeners in rivetted plate girders, between plates or angles rivetted together in rivetted or bolted built-up members and between the top flanges of girders and the undersides of timber transoms are typical corrosion locations. The key feature of rust from steel is that the volume of the rust material is about 8 times that of the parent steel. Therefore the actual loss of steel cross-sectional area is very much less than appears at first sight.

A commonly corroded element is the reinforcement in concrete members. The associated expansion of corrosion products leads to cracking and delamination of the concrete and can result in major loss of member strength.

f) **Cracked** - In relation to concrete, this defect description covers a range of possibilities.

i) **Shrinkage cracks** usually run transversely to the longest dimension of a concrete element. Therefore they are usually found in walls, where they will be vertical cracks, or in footings. Shrinkage cracks have a fairly uniform crack width along their length and tend to occur as a series of roughly parallel cracks.

ii) **Structural cracks** are caused by the application of loads to the concrete members. They are found where the application of loads causes tension in the concrete. In beams they may be flexural cracks or shear cracks.

iii) **Flexural cracks** taper in their width from a maximum at the edge of the concrete to nothing where there is no tension in the concrete. Simply supported beams may have flexural cracks near the middle of the span and these will be widest at the bottom surface of the beam, i.e. the soffit.

iv) **Shear cracks** tend to occur as diagonal cracks near the supports of a beam.

g) **Debris** can accumulate in waterways and can restrict the flow of water. This in turn can cause scouring around the foundations or can divert the flow of water to the extent that adjacent earthworks may be damaged.

h) **De-lamination** occurs in concrete and is usually caused by corrosion of reinforcement. It is more prevalent in walls and slabs where a whole layer of reinforcement can expand due to corrosion and push off the covering layer of concrete.

i) **Distorted** - This term can apply to a number of bridge and culvert elements but is more likely to apply to members made from thin plate material or slender angle or pipe. In these cases, the distortion may be due to mechanical damage from vehicles, dragging equipment or maintenance equipment or may be due to the onset of buckling failure. If there is no evidence that the distortion is mechanical, it would be better to refer to the defect as buckled rather than just distorted.

j) **Fretting** applies to concrete, stone or brick and refers to the loss of surface material due to deterioration of the material. The deterioration may be due to salt damp, chemical degradation of the material or other causes.

k) **Loose components** - Refers to components where fasteners are missing or not fully effective.

l) **Missing components** - Refers to components, typically fasteners, stiffeners or braces which are missing.

m) **Rotting** - Applies to timber elements and should be rare in bridges and culverts because timber transoms will normally fail for other reasons before they rot.

n) **Scoured** - Normally applies to the bed and banks of waterways but can also occur on the batters of cuttings or embankments. Scouring is due to rapidly flowing water picking up and carrying away soil, sand or gravel material. The faster the water flows the larger the particles, which it can dislodge and carry. The main concern is the undermining of foundations or destabilizing of earth batters.

o) **Settlement** is the vertical downwards movement of all or part of a structure due to the compression or failure of soil under the footings. **Uniform settlement** rarely causes concern and is not easily detected. **Differential settlement** can cause cracking in walls and foundations.

p) **Spalling** occurs in the surface of concrete, stone or brick elements. It can occur in un-reinforced elements due to localized concentrations of compressive stress but is usually caused by corrosion of reinforcement in concrete (see also "de-lamination"). The expansion of the corroding steel pushes a shallow cone-shaped piece of concrete from the surface.

q) **Splitting** is a defect associated with timber. Vertical splitting along the length of a timber beam (transom) may make fastenings ineffective but is not as serious, structurally, as horizontal splitting along the length.

r) **Termite damage** - Applies to timber elements and should be rare in bridges and culverts because timber transoms will normally fail for other reasons before being attacked by termites.

s) **Vegetation** - Growth of trees, bushes or some grasses in waterways can restrict the flow of water. This in turn can cause scouring around the foundations or can divert the flow of water to the extent that adjacent earthworks may be damaged.

t) **Track geometric fault** - Often, a track geometric fault is indicative of excessive deflection or settlement of the structure supporting it. This fault description would be used if the nature of the deflection or settlement in the structure is not apparent to the inspector.