CONSOLIDATED RAIL CORPORATION

DETAILED INSTRUCTIONS FOR MAINTENANCE INSPECTION OF BRIDGES

I. GENERAL POLICY AND PROCEDURE

(a) The Bridge Inspector will conduct structural inspections in accordance with Conrail's Bridge Management System (BMS) Policy.

(b) The Bridge Inspector will conduct structural inspections in accordance with Conrail MW 201, "General Instructions for Inspection of Bridges, Tunnels and Culverts."

(c) Standard forms will be used to record structural conditions:

1. MW 203 – Bridge Inspection Report
2. MW 204 – Supplemental Inspection Report
3. MW 205 – Movable Bridge Inspection Report
4. MW 206 – Bridge Sounding Report
5. MW 207 – Tunnel Inspection Report
6. MW 208 – Culvert Inspection Report

(d) Standard equipment to be used by the Bridge Inspector include (but is not limited to):

1. Flashlight
2. Camera
3. Ladder
4. Clearance rod
5. 100 foot tape
6. Track level
7. Hip boots
8. 2 lb. hammer
9. Chipping hammer
10. Chisel and punch
11. Plumb bob
12. Ice pick and pocket knife
13. Binoculars
14. Increment borer
15. Reflective vest
16. Life vest and fall protection
17. Climbing equipment

(e) Reference Marks – The Bridge Inspector will apply reference marks when conditions subject to change require monitoring. Such reference marks will be applied for permanence so that changes in the condition can be reliably identified. It is extremely important for Inspectors to apply reference marks and clearly document them on the Supplemental Inspection Report so that changes in condition can be quantified.

Dye penetrants may be used to identify and define the limits of cracks in metal. The ends of such cracks can be marked for reference by the application of paint at the end of the crack or by applying a punch mark to the metal at the end of the crack.

Cracks in masonry substructure elements may be marked by application of paint on either side of the crack and notation of distance between paint marks. Reference marks can also be applied using chisel to apply cross cuts to concrete and notation made of distance between cross cuts.

Reference pins may be driven into sound masonry on either side of cracks and measurements taken between pins.

(f) Supplemental Information – The Bridge Inspector when required to provide supplemental information such as the location and dimensions of reference marks and sketches illustrating other conditions to be monitored, will make such sketches and notations on MW 204, "Supplemental Inspection Report". Sketches will be made using straight edge and pencil with the scale, if any, noted.

Photos should be taken using 35 mm or digital camera. General view of the condition should be provided in addition to close up views to enable the viewer to completely understand the condition being presented. When necessary, flash attachments should be employed to ensure that the photo is clear enough to discern details. Photo documentation of conditions can also be used as a monitoring tool.

(g) Checking Bridge List – The Bridge Inspector will check all items in the Bridge List for the structure being inspected to ensure that such information is current and correct. Such items as Crossing Name, Vertical Clearance, Bridge Type and Span Lengths (in the instance where replacement structures have been built since the last inspection) will be noted and the bridge list updated.

(h) Nomenclature – The Bridge Inspector will employ standard and generally accepted nomenclature as outlined below for various types of bridges and component parts of such bridges.

(i) Climbing Training – The Bridge Inspector will be trained in proper techniques and use of all protection equipment to be employed in the normal course of bridge inspection. The Bridge Inspector will use proper climbing techniques at all times during bridge inspection.

(j) Condition Codes – In general, the following guidelines will be used in assigning codes to reflect condition of structural components. More precise examples of condition codes are included in the MW 202 sections detailing specific structural conditions.

(1) New condition and/or no defects
(2) Good condition; a few minor discrepancies
(3) Fair condition; extensive minor discrepancies (no repairs required)
(4) Pool condition; defects sufficient to warrant repair; some repair items may be required sooner than others, but in any case, within three years
(5) Critical condition; immediate action needed for purposes of safety; remove from service/down post/speed restriction, etc.

II. BASIC BRIDGE MECHANICS

(a) Forces – The principal forces on structures and components of structures are tension and compression (applied either axially or through bending) and shear. These stresses are found in primary structural members which perform the function of carrying the loads imposed by the dead load of the member itself and the live load represented by the train or vehicle. Such stresses are also found in secondary structural members (such as sway frames and cross bracing) which are designed to resist the tendency for buckling of compression members or to resist such loads as wind on the structure.

(b) Bridge Loads – There are basically two categories of loads to be considered when inspecting a structure. Dead loads are those loads which are due to the weight of the structural elements themselves. Dead loads can be imposed on a portion of a structure due to lateral loads imposed by earth pressure against parapet and spandrel walls of filled arch bridges. These loads are always present.

Live loads are loads which are not always present in the structure but which are imposed on the structure during the passage of traffic, the imposition of wind loads or snow loads, surcharge loadings laterally on parapet and spandrel walls during passage of trains, hydraulic loads due to passage of water, as well as ice and debris loads imposed on substructure elements in rivers and on superstructures during flooding conditions.

(c) Axial Members – Structural components which are stressed principally through the axis of its section. The simplest example is that of a building column which supports a floor system supported on top of the column. The loads imposed on the floor system impart a compressive force down through the column's axis to its footing. The concept of compression is important to understand with respect to buckling of compression members as well as the forces imposed on bracing members subject to secondary stresses.

An example of a material stressed in tension through its axis would be a rope with a weight suspended from it. In this case, the rope is stressed in pure tension through its cross sectional area.

In terms of bridge members stressed axially, the most common example is a truss member. In a simple span truss, the upper chord is considered to carry compressive stress axially through its section. This also holds true for the end posts. A member stressed in tension through its axis would include hip verticals, I-bar hangers and lower chord members. The concept of tension is important to understand with respect to the tendency for the initiation and propagation of cracks in the structural material.

(d) Bending Members – Structural components which are stressed principally in bending are commonly referred to as "beams". Considering the nomenclature of various bridge components, such members subject to beam (i.e. bending) action include: stringers, floor beams, girders and open deck bridge ties.

Through the process of bending, a member is stressed about its neutral axis in both compression and tension. Above the neutral axis, for simply supported beams, the material is stressed in compression. Below the neutral axis of simply supported beams, the material is stressed in tension.

A simply supported beam is one which is supported at each end only. This is in contrast to continuous structures which may be one or more interior supports between the ends of the span. The concept of bending is important to understand with respect to the interaction of tensile and compressive forces and the implications for crack propagation as mentioned above.

(c) Shear Stress – Shearing action is the tendency of a material to separate along a vertical or horizontal plane. An example of pure vertical shearing action would be two overlapping vertical plates fastened together with a bolt. The bolt's cross section where the two plates are held together is subjected to shearing action as the two plates are pulled in opposite directions.

In the case of a bending member, there exists a combination of vertical and horizontal shear. The resolution of these horizontal and vertical shear forces results in a diagonal tension force. The concept of the shear stresses is important to understand with respect to shear cracking of open deck ties as well as the behavior of truss web members.

III. MECHANICS OF MATERIALS

(a) Materials used in the construction of bridges possess various physical properties which determine their suitability for various applications. Some materials are stronger than others in resisting tensile forces (as represented by their tensile strength). Other materials are stronger in compression than tension. Such factors determine the maximum span length that can be attained with a particular material used as a beam. Other factors involve resistance to corrosion, resistance to burning, toughness and ductility of the material and the weight of the material itself.

(b) Stone – One of the first building materials used by man, stone possesses varying properties based on its method of formation. Stone from sedimentary formations such as sandstone differ from stone resulting from volcanic or metamorphic processes in that it is less resistant to abrasion and weathering. But in general, stone is very capable of resisting compressive forces and relatively weaker in resisting tensile forces. This weakness in tension can be attributed to the nature of the material itself (i.e. molecular bonds) as well as the presence of bedding planes and fractures Because stone is weak in tension applications, its use as a beam is severely limited. The most suitable application for stone to take advantage of its strength in compression, is in the construction of arches.

(c) Concrete – Closely related to stone in its strength characteristics is concrete. Concrete's constituent elements are Portland cement, fine and course aggregates and water. Various proportions of these elements result in concrete of different strengths. In addition, admixtures can be used to accelerate set, allow curing in cold weather, entraining air in the mix and to produce other properties which may be desirable for a particular application.

Concrete, like stone, is stronger in compression than tension. In order to employ concrete in beam applications, steel, in the form of reinforcing bars or pre-stressed strands, is placed in the tension zone of the concrete beam to resist tensile forces.

(d) Timber – Probably older even than stone as a construction material, timber is more versatile in application, lighter in weight and more easily worked than stone. Timber is a fibrous material which is nearly equally as strong in tension as in compression parallel with the grain of the wood. Timber is resilient and not subject to sudden brittle failure.

Timber's drawbacks include its susceptibility to fire damage, the tendency to weaken due to rot or insect infestation, the tendency for mechanical wear (e.g. plate cutting of ties), as well as its weaker resistance to compression perpendicular to its grain which can result in crushing of portions of an otherwise undamaged structural member.

(e) Steel – The greatest invention of the industrial age, steel possesses physical properties which make it the most versatile, dependable and usable construction material. Steel is ductile and tough, meaning it can absorb and dissipate stresses which in a more brittle material would lead to crack propagation and sudden failure.

The drawbacks of steel as a construction material include its tendency to corrode, the potential for damaging its properties through overheating due to fires and the changes it its molecular properties due to cyclic stresses, commonly referred to as fatigue.

IV. THE TRACK

(a) The first item to be inspected when approaching a bridge for inspection is the condition of the track structure. Observe whether the track is level or on a grade and if alignment is tangent or curved. If on a curve, note how superelevation is provided.

(b) Inspect the track for line and surface. Determine whether there is a smooth transition between the approaches and the bridge structure itself. If discrepancies in line and surface of the track on the approaches and/or across the bridge are observed, measure the amount and nature of these discrepancies and ascertain probably causes.

(c) Inspect the condition of the approach track on both ends of the bridge. Note whether the approach track ties are fully cribbed and observe the condition of the shoulders and the adequacy of wingwalls and parapets on "U" walls to retain ballast. Determine whether the rails are seated in the tie plates and whether there is any evidence of tie plate movement.

(d) Inspect the condition of the track rails across the bridge. Check all joints and fastenings. On through truss bridges and on viaducts where tower legs extend laterally beyond the limits of the superstructure and are subject to damage from derailed equipment, check the adequacy of inner track guard rails. (Reference MW 4, "Construction and Maintenance Practice", Section 145.0).

(e) If the discrepancies fall outside the limits of the MW 4 for the class of track being inspected, immediately notify the dispatcher, the Engineer of Track and the Track Supervisor of the condition, as well as the office of the Manager – Bridge and Buildings.

V. THE DECK

(a) Walkways and Railings – Check the adequacy of all walkways, railings and refuge bays. Handrails should extend no less than 42 inches (plus/minus 3 inches) above the walking surface and be rigidly attached to prevent any lateral or outward movement. Note that standard walkway plans call for a railing height of 44 inches for new construction. Walkway grating should be secured at the ends; walkway planking should be free from extensive splitting and must be checked for excessive deflection as well as rot.

(b) Ballast Deck – Ballast decks can be constructed of concrete, steel plate or solid timber mats. Each presents unique problems and must be inspected with an understanding of the causes and effects of deterioration. In general, check for adequacy of ballast section on the bridge. Observe whether the parapets have been raised above original construction and check the ballast depth at each end of the bridge. Greatly overloaded ballast section greatly increases the dead load and total loads on superstructure and substructure elements.

Also check for evidence of muddy or pumping track which would indicate drainage problems. Of particular concern in any case is where there is water infiltration through the deck, is the subsequent deterioration of the bridge floor system components.

(1) Concrete decks must be checked for leakage through the concrete as evidenced by efflorescence through cracks. This occurrence indicates the absence of or breakdown of a waterproofing system on the deck. Check for spalling of the underside of the deck and note the depth of such spalls and the exposure of reinforcing steel. **Condition 4: Slabs which are extensively and deeply spalled and which have begun to develop holes.**

(2) Timber decks must be checked for conditions of rot due to inadequate waterproofing system. White discoloration of timbers on the underside of the deck as well as soft, punky texture indicates the initial stages of dry rot. If the ends of the timber deck are exposed, hollowed areas may be observed. These areas should be probed to determine the extent of the hollowed areas. In many cases, the followed area may be localized at the ends where guard or parapet timbers are lagged into the deck timber. **Condition 4: Solid timber decks which exhibit extensive rot under the track area.**

(3) Steel deck plates must be checked for signs of corrosion and perforations which would allow the loss of ballast in the track. **Condition 4: Steel deck plate exhibits extensive reduction under the track area and its beginning to lose ballast.**

(c) Open Deck – The integrity of the track on an open deck bridge is entirely dependent upon the bridge ties, so it is vitally important that the Inspector understands where and what kind of problems are likely to develop.

(1) Inspect the size, spacing and depth of ties. As beams, bridge ties require greater depths, depending upon how far apart they are supported (i.e. lateral distance between supporting stringers or girders). Insufficient depth of ties on widely spaced supports may result in shear cracking of the tie. These cracks commonly begin at the notch where the tie is dapped to fit the top flange of the support. Shear cracks extend diagonally from this notch upwards, toward the center of the tie. **Condition 4: Ties are substandard depth and exhibit extensive shear cracking.**

(2) Inspect the deck hardware and fastenings. Hook bolts should be spaced according to the requirements of the MW 4 for either CWR track or jointed track. Check for the effectiveness of hook bolts, noting whether the hook is perpendicular and in contact with the underside of the top flange. Check spacing bars and spacing blocks. On older decks, in the absence of spacing blocks and spacing bars, check the condition of guard timber. **Condition 4: Absence or ineffectiveness of hook bolts.**

(3) Inspect the ties for wear. Basic deficiencies of bridge ties, in addition to shear cracking mentioned above, is tie plate movement and mechanical wear of the tie surface under the tie plate, spike killed condition and tie plate cutting condition where the tie plate has worn into the surface of the tie. Particular attention should be given to conditions on superelevated track. The ends of ties on the low side of the curve will have a tendency to crush if the track speed is significantly lower than the speed for the design superelevation in the deck.

In contrast, on high speed track, insufficient superelevation for track speed or poor alignment or transition from the open deck to the approach track, may cause noticeable tie plate movement. Note locations where there is evidence of tie plate movement and/or plate cutting toward the high side of the curve.

Where there is jointed track, rail ends may be bent and the ties under the joint become plate cut and crushed over time due to rail movement. In any case, it is important to consider a tie deck in its entirety. Individual ties may exhibit various defects but not in sufficient number to warrant complete deck removal. **Condition 4: Sufficient number and type of defects to warrant consideration for tie renewal program.**

(4) Bridge Tie Analysis – When examining bridge ties for defective conditions, the following should be used as general guidelines:

Plate movement: Evidence of lateral plate movement on the tie of at least ½ inch. Note the presence and condition of plate holding spikes.

Spike killed: Rail holding spikes loose and ineffective. Spikes lifted to the point where they are not effective in restraining rail movement. Note where ties have decayed under the tie plates.

Shear cracked: Conventional cracking of ties due to beam action and inadequate tie depth, cracks originating at the dap and proceeding diagonally upwards into the middle third of the tie. Also, note condition where derailed or dragging equipment has cracked the middle third of the tie, reducing its effectiveness as a beam.

Plate cut: Tie plates cut into the tie at least the depth of the tie plate thickness.

VI. STEEL GIRDER SUPERSTRUCTURE

The Inspector must understand the basic difference between a deck girder and a through girder bridge. The deck girder bridge is the simpler of the two since it transmits imposed loads directly through the girders into the bearings and, hence, into the substructure. The through girder, in contrast, consists of a floor system which must transmit imposed loads through various floor system components and connections to the girders and then the bearings and superstructure. The transmission of loads through the superstructure is defined by the load path. The Inspector should visualize the load path to better understand the forces imposed on structural elements.

(a) Deck Girder – This superstructure consists, usually, of a pair of girders tied together with cross frames, diaphragms and/or lateral bracing. An open tie deck or ballasted deck on concrete, timber or steel is located on the top flanges of the girders. Loads transmitted from the deck go directly into the girders and then to the bearings.

(1) Bearings – The Inspector should first inspect the bridge seat and bearings. The Inspector should remove accumulated debris, soil or ballast. Such accumulations retain moisture and will accelerate the corrosion and "freezing" of expansion bearing elements as well as cause reduction in bearing stiffeners and girder webs. "Frozen" expansion bearings can lead to damage of the bridge seat as thermal expansion and contraction may initiate cracks in the bridge seat material. **Condition 4: Extensive reduction of webs and stiffeners, holes and loss of section; a large enough loss of section to warrant engineer's review.**

(2) Blocking/Shims – The presence of timber blocking should be noted. This is a non-standard method of raising bridge girders, fabricated steel grillages, solid steel billets and properly designed concrete raising blocks are preferable to timber blocking. The Inspector should measure the height of timber blocking, its condition noting any crushing or evidence of rot. Also, the adequacy of girder anchorage to the bridge seat should be noted. In most cases, anchorage in the presence of timber blocking, is inadequate. **Condition 4: Timber blocking beginning to crush, shows signs of rot. Girders do not pump appreciably on blocking yet.**

(3) Bridge Seat – While inspecting the bearings, the Inspector must make a point to closely inspect the bridge seat. To transmit the loads from the girder ends into the substructure, there must be a transition usually from steel to either concrete or stone. The allowable compressive strength of steel is greater than the bridge seat material, so it is necessary to provide enough bearing area for the proper transmission of the girder reaction into the bridge seat without damaging the bridge seat material. This is commonly accomplished by providing a bearing or masonry plate with sufficient area to transfer loads without exceeding the bearing capacity of the bridge seat material. **Condition 4: Inadequate bearing area of masonry plate allows bearings to cut into the bridge seat and the girders to pump under live load. Inadequate masonry plate thickness will allow the plate to deform as it punches into the bridge seat. Also, deterioration of the bridge seat material with consequent loss of bearing area due to spalled concrete or cracked bearing stone.**

(4) Cross Frames/Lateral Bracing – The Inspector must check for deterioration of cross frames through the deck girder spans. The cross frames hold the girders in alignment with each other so that they transmit loads as a unit. Cracks in cross frame connections or sheared connections may indicate problems of excessive movement of one girder with relation to the other, (e.g. one girder bearing pumping excessively).

Top lateral bracing in simple spans serves to resist the tendency of compression elements to buckle. The unsupported length of the compression member is an indicator of the "slenderness" of the member. The distance between top lateral bracing connections along the top flange is known as the unsupported length. Broken, corroded and missing top laterals and connection plates increase the unsupported length of the compression flange. The absence of effective top flange, lateral support can lead to excessive movement of the top flange which with an open deck, could present track alignment problems under load. **Condition 4: Destruction of enough top lateral angles and connections in a row (either through corrosion or impact damage) to warrant an engineer's review.**

(5) Web – The girder web plate should be checked for signs of distortion and distress. At the bearings, loss of sufficient web and stiffener material may result in the beginning of localized web buckling. Fire damage can also warp web plates. Vehicular impacts may be responsible for flange and web damage over highways. In addition, out of plane bending of the top flanges and the top section of the web on open decks with widely spaced girders can result in web cracks developing in the fillet of the top flange angle/girder web interface. Note all locations and extent of holes, cracks or distortion in web plates. **Condition 4: Extensive reduction and holes in web and stiffener material at bearings, requiring an engineer's review. Cracks, tears or rust holes through webs at locations other than the bearings which are referenced and do not exhibit any change, subject to an engineer's review.**

(6) Top Flange – The top flange can be made up of multiple cover plates riveted together to top flange angles (in the case of riveted built up girders), welded top flange plates of varying thicknesses (in the case of welded built up girders) or simply the top flange of a rolled section (in the case of multi-girder bridges or standard steel trestle). In spans simply supported at each end, the top flange will be in compression and is not usually a location where crack propagation is a problem.

The top flange should be checked for straightness and alignment. Bent or distorted top flanges can result from derailment or dragging equipment damage. In addition, tie wear of the top flange can result, in extreme cases, of extensive damage to rivet heads as well as reduction of top flange cover plates. Reduction of top flange material combined with out of plane bending of the flange can produce longitudinal cracks in the top flange. Such cracks should be marked and locations of cracks and top flange reduction indicated on the bridge inspection report. **Condition 4: Extensive loss of rivet heads requiring an engineer's review to determine whether the top flange cover plates are still effective as designed. Also, cracks due to out of plane bending of flange under bridge ties, when such cracking is extensive.**

(7) Bottom Flange – The bottom flange is generally made up as is the top flange (i.e. either with riveted cover plates, welded plates of variable thickness or width, etc.). Of vital importance is the understanding by the Inspector that the bottom flange of a simply supported girder is in tension and is subject to crack initiation and propagation. The bottom flange, being the lowest point on a deck girder bridge, is particularly susceptible to impact damage by vehicles (over streets) and floating debris (during high water over streams and rivers).

Bottom lateral system connection plates may hold debris which retains moisture and may accelerate corrosion of the bottom flange angles where the connecting plate frames into the girder. Bottom flanges must be checked closely for cracks, corrosion and steel reduction, particularly at mid-span where the bending moment and consequently, tensile stress, is greatest.

Impact damage to the bottom flange can result in torn or separated cover plates. All damage resulting from vehicle impacts must be inspected closely. The Inspector should thoroughly clean the area damaged and inspect for the beginnings of cracks. All bottom flange damage, whether by corrosion, impact damage or other means, should be referenced from the end of span and carefully documented.

Crack propagation through welded built-up girders is of major concern. Riveted and bolted built-up girders possess internal redundancy and cracks will not readily extend directly from one plate to another plate. **Condition 4: Any reduction, notching, cracking or impact damage which requires an engineer's review and which has not shown noticeable change since last inspection. Noticeable changes (e.g. significant propagation) may warrant Code 5.**

(b) Multi Girder – This superstructure consists of a series of girders on relatively close spacing and normally carry a ballasted deck. In comparison with the two girder system described in VI (a), these girders are generally shallower built-up or rolled sections (i.e. I-beams). A longitudinal trough superstructure is another example of the multi-girder principle. Cleaning the bridge seats between the troughs is important for assessing the condition of trough webs.

Because of the close spacing of these girders and potential for debris to collect on the bridge seats, it is important to clean and closely examine the bearing areas for signs of corrosion and deterioration. Even though the members are redundant and live loads are distributed over them by the ballast deck, load bearing capacity problems can still develop when a series of girders in close proximity to one another exhibit pronounced reduction.

(c) Through Girder – This superstructure consists of girders which carry an open or ballasted deck on a floor system consisting generally of floor beams and stringers framed into the girders. Exceptions to this description include through girder superstructures which carry the deck on a series of closely spaced floor beams (i.e. there are no stringers), which carry solid or closely spaced timber deck ties directly on the bottom flanges of the girders or which carry the track on a solid transverse trough system. Each floor system is addressed separately below.

In general, the inspection procedures for the through girder itself will follow those of the deck girder described in VI (a). Differences to be noted: top flange compression bracing on a through girder is proved by knee braces (i.e. floor beam brackets) instead of top lateral bracing and bearing and bridge seat inspection should also include inspections of independent end bearing stringers.

(1) Floor Beam – The Inspector should inspect the floor beam to girder connection for condition of connecting rivets and bolts. All fasteners should be tight and underformed. Check web for evidence of cracks, especially where the floor beam ends have been coped around the girder bottom flange. Records should be kept of damage of floor beam connections due to corrosion and impact. **Condition 4: Extensive sheared or broken rivets or bolts. Corrosion and/or cracking which has not changed appreciably since the last inspection but which requires an engineer's review.**

On open deck bridges, the floor beam top flange should be checked for impact damage from derailments or dragging equipment. Where the top flange has been deformed due to impact, close examination for cracks in the flange should be made. The top flange is also susceptible to corrosion. The Inspector should check for adequacy of rivets/bolts connecting the cover plates. **Condition 4: Severe and extensive reduction of rivet heads with no separation of cover plates. Impact damage and flange deformation which has not changed since the last inspection but which requires close examination for cracking.**

Bottom flanges should be checked for impact damage, tears in cover plates and bottom flange angles. Check for corrosion and reduction of the bottom flange in areas where it comes into contact with or is connected to bottom lateral system. **Condition 4: Severe notching due to corrosion or impact damage to bottom flange, particularly towards the area of higher bending moment.**

Webs of floor beams should be checked for impact damage. Also, corrosion and web reduction where stringer connections frame into the floor beam should be closely checked. The stringer to floor beam connection is dependent upon the integrity of the web material. In cases where floor beams are encased in concrete and the floor beam to girder connection is not encased (i.e. open pocket) there is the possibility of web reduction along the edge of the concrete encasement. **Condition 4: Extensive web reduction and holes around the stringer connection and the interface between end of concrete encasement and exposed floor beam web.**

(2) Stringer – The stringers carry the direct track load and transfer this load into the floor beam through the stringer to floor beam connections. It is important to check stringer connections for loose/missing rivets or bolts. This is particularly a problem in the case of independently bearing end stringers. Check the bridge seats for wearing of masonry plates or other bearing elements cutting into the bridge seat or crushing timber blocking which result in pumping of end stringers. This condition can initiate a prying action at the first floor beam connection, resulting in broken rivets/bolts and cracks in connection angles. Another factor to consider is stringer continuity from one bay to the next through the floor beam web. Stringers connected together end to end through the floor beam web can act as a continuous span with the introduction of tensile and prying forces in the top half of the stringer. **Condition 4: Loose/missing rivets or bolts at the stringer to floor beam connection. Cracks in connection angles requiring engineer's review.**

On open deck bridges, check the top flange for evidence of excessive tie wear, corrosion and thinning of top flange. On widely spaced stringers, top flange angles of built-up members may exhibit longitudinal cracks on the same side as the rail caused by repetitive bending due to track loads. **Condition 4: Extensive cracking of top flanges.**

Bottom flanges should be checked for notching due to corrosion and impact damage. Check where lower laterals cross under or may be attached to stringers, as this is an area which accumulates debris, holds moisture and can accelerate corrosion. **Condition 4: Severe reduction, notching or cracks in bottom flange, particularly towards the center of span at point of maximum moment. Subject to engineer's review.**

Check the webs of stringers for corrosion and impact damage. Of critical importance is web integrity at end of span near stringer to floor beam connections. **Condition 4: Extensive reduction/holes in webs near stringer to floor beam connections. Subject to engineer's review.**

(3) Transverse Trough – This floor system represents difficulties for inspection as the trough to girder connections are not directly observable, being buried by the track ballast. The Inspector should closely inspect the outsides of the girders for signs of web corrosion. In addition, these deck structures may suffer from inadequate drainage and bottoms of troughs should be inspected for corrosion damage.

(4) Floor Beam Timbers – This floor system may be viewed as a special application of a conventional open deck, except that the timbers in this case must be deep enough (due to the longer span between bearings on the girder flanges) and spaced closely enough to provide direct support and transfer of live loads from the rail to the girders. The Inspector should check the timbers for evidence of shear cracking, inadequate bearing area on the girder flanges (evidenced by crushing) as well as check the girders for signs of bottom flange distortion or web crack initiation.

IV. STEEL TRUSS SUPERSTRUCTURE

The through truss superstructure (and in many cases, the deck truss superstructure) have certain features similar to the through girder. A truss may be viewed as a large, open we girder. Shear forces carried through the girder web plates, is carried by diagonal web members in the truss. Likewise, inspection items detailed in IV (a) 1, 2, 3 and 4 regarding bearings, blocking/shims, bridge seat and bracing apply equally to truss superstructures as to girder superstructures.

The floor systems of these bridges are generally of the same type of construction and inspection items which apply to the through girder floor system also generally apply to the through truss and deck truss floor system. A key difference in these floor systems may be the greater length of bays between floor beams in a truss floor system. Longer stringer spans on truss bridges result in higher end reactions and greater moment in the stringer. There is also a greater degree of prying action at the stringer to floor beam connection due to the longer stringer spans and the factor of continuity mentioned above. Finally, in pin-connected trusses, if there is sufficient slackness of lower chord eyebars, it has been found that the floor system may be subjected to axial tensile forces for which it was not originally designed, resulting in additional stress to the stringer to floor beam connections.

Floor system inspection concepts for truss superstructures which differ from those of through girder floor systems (e.g. stringer bearings on top flange of floor beams in deck truss floor systems, etc.) are explained separately below.

(a) End Post – The end post of a simply supported through truss carries the end reaction of the span into the bearings and bridge seat. The end post is a compression member and subject to buckling should an eccentricity be introduced into the member due to impact damage. The end posts should be inspected for evidence of corrosion, particularly in the area of the bearing. Prior evidence of impact damage should be referenced and monitored for change. Also, prior repairs of damaged end posts should be checked for continued effectiveness. Portal bracing should be checked for signs of impact damage due to high or shifted loads and adequate connection to end post. **Condition 4: Evidence of impact damage including cracks and tears of steel, pronounced bows, kinks or misalignment of end post.**

(b) Hip Vertical – This is usually the first vertical web member at the end of the bridge, connected at the junction of the upper chord and the top of the end post. The hip vertical is subject to tensile stress and is a fracture critical member of the truss. While the theoretical stress in this vertical member is axial, in actuality, there are out of plane bending stresses introduced into the member from the floor beam connection. This out of plane bending can serve to initiate cracking in the top third and bottom third of the vertical member. Each hip vertical should be examined closely for cracks in these areas as well as at gusset plate connections. In addition, weld repairs can introduce residual stresses which can serve to initiate cracks in the parent metal. All weld repairs should be closely inspected for defects.
Condition 4: Corrosion which reduces the effective cross section of any part of this tension member. Evidence of cracks or other distortions due to corrosive reduction or impact damage to the member or connection plates. All deficiencies noted subject to engineer's review.

(c) Counters – On pin-connected trusses, eyebar web members are incapable of sustaining compressive loads. Therefore, all eyebar web members are designed to resist tensile forces. For this reason, in panels where stress reversal (i.e. due to shear) occurs, counters are provided to resist the tensile stress in the panel. As a general rule, counters will be more slender than the main diagonals. The counters should be checked for slackness. The counters at rest should not be tight, as this indicates that they are already subject to tensile stress due to the dead load of the truss (i.e. without the introduction of live loads). As with any other tension member, counters should be checked for corrosive reduction, weld repairs and impact damage. **Condition 4: Counters stressed with no live load on bridge. Evidence of section loss, cracks or impact damage.**

(d) Other Web Members – Vertical and diagonal web members of trusses, depending upon the truss design, can experience tension, compression or stress reversals (i.e. go from tension to compression under moving loads). All web members should be closely examined for impact damage, corrosion damage resulting in significant loss of section and cracks. Keep in mind the concept of out of plane bending with reference to floor beam to vertical connections. Location of deficiencies of truss web members should be noted and referred to the engineer for further evaluation. Standard reference nomenclature using panel point designations should be used to identify the specific member. Panel points are designated by their location on the lower (L) or upper (U) chords and truss members are identified by the panel point designations at their ends. (Example: The first end post on a truss would be designated L0-U1; the first hanger L1-U1, etc.).

(e) Upper Chord – As explained with regard to the top flanges of girders, stringers and floor beams, the upper chord of a simply supported truss carries compressive forces. The upper chord should be checked for alignment, corrosion and cracks. Check all sway bracing connections. On pin-connected trusses, closely examine the pin plates for cracks, including evidence of cracks which may occur under the nut or pin keeper. On riveted trusses, check all gusset plate connections at panel points where vertical and diagonal web members are connected to the upper chord.

(f) Lower Chord – As explained with regard to bottom flanges of girders, stringers and floor beams, the lower chord of a simply supported truss carries tensile forces and is considered a fracture critical member. It is extremely important that the lower chord of any truss be closely examined for evidence of impact damage, severe corrosion or the presence of cracks. Pin-connected truss lower chords are made up of eyebars. Pin locations should be checked for wear by the presence of rust bleeding from the pin area. Pins should be visually checked where possible. Check for spacers between eyebars. Check the alignment of all chord and web eyebars joined around the pin.

Check all lower chord sway bracing connections. These are generally large horizontal plates which hold debris and are subject to corrosive reduction. Check bracing below the deck for continuity from one truss to the other.

(g) Truss Floor Systems – Several variations on floor systems found on truss bridges that must be considered which differ from floor systems in through girder bridges include: (1) transverse trough floors which frame into the lower chord of the truss and (2) deck trusses in which stringers bear on the top flanges of floor beams rather than framing into the floor beam webs. Both of these situations should be closely inspected with respect to load path implications.

VIII. CONCRETE AND MASONRY SUPERSTRUCTURES

The Inspector must be aware of the various forces existing in concrete and masonry in bridge superstructures and how deterioration of structural components may affect the load carrying capacity of the structure. This section addresses concrete slabs, concrete beams (i.e. conventionally reinforced and prestressed), concrete and stone arches and components such as parapet and spandrel walls. Also included with this training module is the concept of stone and concrete culverts.

(a) Concrete Slab – Concrete slab bridges represent the unique situation where the superstructure also serves as the deck. These bridges are generally cast in place, conventionally reinforced concrete construction. Also included in this category, for purposes of inspection, are rail stringer bridges encased in concrete.

Since the top of the deck/slab is not visible for inspection, determination of the extent of deterioration to the slab is limited entirely to an inspection of the underside of the structure. The most obvious and early evidence of deterioration involves the presence of cracks on the underside of the slab. The Inspector should note the extent and size of cracking. Small temperature and shrinkage cracks may be present from the slabs initial construction and early use and may not have changed since they originally developed. These cracks may be characterized as hairline cracks and do not in themselves represent a significant deficiency.

Of a more serious nature are larger cracks which exhibit water leaching through the concrete from the track structure above. Seepage of water through cracks may dissolve out calcium hydroxide and other constituent materials in the concrete and is evident in the form of efflorescence. The importance of noting this condition, its extent and severity, is the threat to the reinforcing in the slab. Corrosion of the reinforcing bars leads to rust build-up. The expansive nature of rust eventually enlarges the existing cracks and initiates *spalling* (i.e. loss of concrete between the fracture surfaces). The combination of reduction in area of the reinforcing steel and the loss of concrete bond around the reinforcing steel due to extensive spalling, can reduce the effective load carrying capacity of the slab.

Another deficient condition common to concrete structures is *scaling,* which is the gradual and continuous loss of surface mortar and aggregate. This condition is more commonly found on concrete surfaces exposed to chemical attack, such as vertical faces of concrete abutments exposed to road salts. However, surface scaling can exist on virtually any concrete surface, including the undersides of slabs, as well as vertical faces of spandrel and parapet walls. The Inspector should note the presence of surface scaling of concrete and its extent. Over roadways, extensive scale may have to be removed and should be so noted on the inspection report.

(b) Concrete Beam – Conditions to be noted by the Inspector with respect to concrete beams include cracks, efflorescence, spalling and scaling as explained with respect to concrete slab superstructures. In addition, several concepts unique to various types of beam construction must be considered. It is important to remember that any significant cracks in concrete beams must be observed under load. Active crack propagation, particularly in the case of prestressed concrete beams, is a sign of potential beam failure.

1) Diagonal cracks in concrete beams may be an indication of potential shear failure. Concrete beams are designed to fail in tension, giving advance warning of incipient failure by crack initiation in the tension zone and elongation, distorting and failure of reinforcing steel, rather than sudden brittle failure in compression of the concrete. Advanced and extensive cracking in the tension zone of concrete beams should be observed under load, noting any evidence of excessive deflection or crack enlargement.

2) Vertical cracks in concrete beams may be an indication of excessive stressing of the beam in bending. Close inspection of cracks and reference marks to indicate their extent and size must be made.

(c) Prestressed Concrete Beams – These beams differ from conventionally reinforced concrete beams in that prestressed steel strands are present in the bottom of the beam. During shop fabrication, a series of steel strands are drawn to a predetermined tensile force and elongation. While held in place the concrete is placed and cured. Once the concrete is cured, the prestressed strands are released. The strands, now bonded to the cured concrete, in returning to their pre-elongated condition, introduce compressive stress into the bottom of the concrete beam. This initial compressive state, unloaded, provides additional reserves of strength in bending, considering that live loads on the structure will introduce tension in the bottom of the beam. Thus, prestressed concrete beams will exhibit relatively low tensile stresses under load and tension cracking of the bottom flange of the beam is avoided.

Problems the Inspector must be aware of generally involve defects which become evident during the early service life of the prestressed beam which can be the result of faulty design, fabrication or construction. The solid concrete end block at the beam bearings may exhibit horizontal cracking due to inadequate stirrups or ineffectiveness or lack of strand sheathing at the ends of the beams during fabrication.

Inadequate design for deflection under service loads can result in crack initiation in the tension zone of the beam, if the tensile forces introduced exceed the tensile strength of the concrete. This condition can lead to further problems in corrosive environments where chemical attack of the prestressed tendons takes place.

With regard to adjacent box beam structures, it is important that proper construction techniques are followed. The adjacent box beam superstructure is similar to a slab in that each beam is required to carry live loads in unison. Box beams have shear keys cast into them and when placed side-by-side these shear keys are filled with grout. In addition, steel rods or cable are placed transversely through the beams and tensioned to hold the beams together to perform as one unit under live loads. Failure of the beams to act in unison can result in overstress of individual beams, leading to further deterioration of individual beams.

(d) The Arch – The arch transfers loads generally through compression. Arches can be earth filled structures with track and subgrade supported directly over the arch and retained by spandrel and parapet walls. Arches can also support the track on open spandrels (e.g. a series of columns rising from the arch to support the deck slab and track structure). Arches can be constructed of reinforced or unreinforced concrete or of stone.

1) Earth filled stone arches should be inspected for adequacy of drainage. Normally drain holes or pipes will be present through the arch either directly below the earth fill on either end of the arch span, or laterally through the spandrel wall. Inadequate drainage of the subgrade not only adversely affects the track structure but results in accumulation of water behind the spandrel walls and water infiltration through stone joints in the spandrels and the arch itself. Washing out of mortar between the stones and the expansive action of freezing, can cause misalignment and cracking of stones. Break down of drainage and waterproofing systems is evident in winter by the presence of icicles through the masonry joints.

While earth filled concrete arches can present some of the same problems due to lack of adequate drainage and waterproofing, generally the consequences for the integrity of the arch are not as severe due to the absence of open joints. However, concrete spandrel walls can suffer deterioration due to freeze/thaw cycles caused by inadequate drainage.

2) Spandrels and parapets are subjected to lateral earth loads and surcharge from live loads which depending on the height of fill retained and the close proximity of the track can result in displacement of the spandrel and/or parapet walls. Parapets raised over the years with either timber or concrete, increase the lateral loads on the spandrel wall. The Inspector should note extent of past parapet raises and examine the ends of the arch barrel for signs of cracking or displacement. Cracks and separations in the ends of the arch ring due to lateral displacement of spandrel stones can result in loss of subgrade and ballast from the track structure.

3) Differential settlement of arch foundations can have a catastrophic affect on the structure. While inspection for scour and settlement is covered fully under SUBSTRUCTURES, it is important for the Inspector to remember that, especially in the case of stone arches, that settlement of piers or abutments can cause loss of the arch shape. The shape of the arch is key consideration in its ability to transfer loads effectively. Loss of the arch shape will result ultimately in loss of arch stones and failure of the arch structure itself. Any evidence that the arch shape is not symmetrical or presence of excessive cracking or displacement of stones, should lead the Inspector to check closely for signs of undermining or settlement.

(c) Culverts – The subject of culvert inspection covers a wide range of construction types. In many cases (e.g. stone arches, concrete boxes, concrete slabs, timber boxes, etc.) the same inspection criteria which applies to the larger bridge structures applies to culverts also. This section will address the concepts which are unique to culvert inspection. Culvert inspections must be documented on Form MW 208.

It must be kept in mind that culverts are generally drainage structures which experience water flow on an infrequent basis. Inspection of culverts is usually not restricted by water depth, since there are times of the year when the culvert is dry. However, it is important to keep in mind the need to identify situations where Confined Space Entry limitations may preclude close inspection of culverts.

A permit required confined space has one or more of the following characteristics:

- Contains or has potential to contain a hazardous atmosphere.
- Contains a material that has the potential for engulfing an entrant.
- Has an internal configuration such that the entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross section.
- Contains any other recognized serious safety or health hazard.

Refer to the end of this section for Conrail Policy and Procedure on Permitted Confined Space Entry.

1) Load Distribution – Live load bearing pressures on culverts are dependent on the height of cover over the culvert. The greater the height of fill, the greater the dead load pressure exerted and the less significant, relative to the total load, the live load becomes. Pressure distribution based on an assumed 1:1 slope (e.g. for every foot of depth, soil distributes the load outward one foot) is a good conservative estimate of the effect of live loads on culverts.

2) Stone Arch Culverts – Load distribution is especially important to remember with regard to stone arch culverts. As mentioned previously, arches transmit loads through compression. When there is sufficient fill material over the culvert, all loads are transferred through the structure by the compression of stones in the arch ring. When there is very shallow cover, however, point loads from the passage of trains, are imposed on the arch stones and can cause displacement and/or cracking of ring stones as well as deterioration of abutment stones. The Inspector should sight down the length of the culvert to detect any signs of misalignment or settlement of abutment stones.

3) Stone Box Culverts – Similarly, shallow cover over stone boxes accentuates the effect of live load on the culvert. Cracked and displaced roof stones, as well as deterioration and displacement of abutment stones, may result. As in the case of stone arch culverts, the Inspector should sight down the length of the culvert for evidence of abutment stone settlement or misalignment. The Inspector should locate the track centers in relation to the deterioration in the culvert and so note on his Supplemental Report.

4) Rigid Pipes – Reinforced concrete and heavy steel or cast iron pipes possess structural strength which enables the pipe to resist imposed loads without the benefit of the surrounding soil. Common problems associated with these pipes include joint separation caused by either differential settlement of pipe sections or lateral displacement of headwall units due to scour. The Inspector should note all such irregularities with respect to the location of the track.

5) Flexible Pipes – Thin walled corrugated metal pipes are actually composite structures with relatively little resistance to bending on its own. These pipes require the support of the surrounding soil which, when properly compacted, provides lateral support to the pipe walls. The interaction of the pipe and soil results in ring compression in the pipe. The Inspector should be alert for evidence of water infiltration around the outside of the pipe which can result in the washing away of supporting soil. The Inspector should look for evidence of pipe distortion which can result from improper preparation and installation of backfill material.

IX. TIMBER STRUCTURES

This discussion of timber structures deals primarily with the most commonly found types of undergrade timber bridges (i.e. open and ballast deck timber trestles). Many of the concepts covered will apply also to timber box culverts and overhead timber bridges. Bridge ties are not separately considered here. (For complete discussion of Bridge Ties, see Section V). The key idea to remember concerning timber structures is that conditions can change significantly from one inspection to the next. Many times conditions of decay not evident in one inspection may suddenly become obvious due to crushing of the rotted member. Drift accumulation and associated fire hazards may occur between inspections. For this reason, timber structures are inspected at six month intervals.

A detailed timber inspection report should be prepared on at least one year intervals to identify and monitor changes in condition of individual timber components. This report should identify the stringer size, kind and configuration of stringers in each panel, number of piles or posts in each bent and the location and type of any repair.

a) Stringers – The Inspector should be aware that the timber stringer is subjected basically to the same stresses as those for stringers consisting of other materials. Timber stringers are subjected to bending stress which, in a simple span, imparts tensile stresses in the lower portion of the stringer and compressive forces in the upper portion of the stringer. Unlike steel stringers, timber stringers generally have a constant cross section, meaning that considerations concerning webs and flanges (as in the case of steel beams) do not apply.

Timber stringers on open deck trestles typically span about twelve feet. The stringers are built in chords of three timbers side by side (per rail), connected with bolts and washers to serve as one structural element under load. The three stringers are lapped so that only one inside stringer or two outside stringers have end bearings on the same cap. Timber stringers on ballast deck trestles are spaced evenly apart and bear in an alternating fashion on the cap.

The Inspector should check all locations where timber stringers are fastened either together or to substructure elements (e.g. caps) and where ties are pinned to the tops of stringers on open deck trestles. Areas around fastenings (usually steel pins or bolts) should be checked for evidence of mechanical wear or rot. Fastenings are applied through holes which have been drilled through the timber. Treatment designed to protect the timber has been compromised at these locations. In addition, the tendency for the timbers which are pinned together to move in relation to one another can result in mechanical wear and enlargement of the hole. This enlargement allows for introduction of moisture and consequent rotting around the connection. Where stringers bear on timber caps, extensive rot can result in a reduced effective bearing area of the end of the stringer. Timber is weakest in compression perpendicular to the grain and timber stringers may begin to fail at their bearings due to compression. **Condition 4: Extensive rot at stringer ends where pinned to timber caps.**

The Inspector should also check stringers for impact damage. Cracks of sufficient size to reduce the effective section of the stringer may cause the overload of adjacent stringers. Scrapes and cuts of stringers may also remove the protective treatment of the timber and allow for accelerated deterioration due to exposure to the elements. **Condition 4: Impact damage resulting in extensive cracking and loss of section.**

Probably the most frequent damage occurring to timber stringers is due to fire. The Inspector, upon discovering fire damage to timber stringers, should scrape or cut away sections of charred wood to determine the effective remaining section of timber. The dimensions of remaining effective section should be recorded and reported to the engineer for review.

b) Carbeams/I Beams – While these bridges do not represent timber superstructures, they are examples of trestles with timber substructures (i.e. bents). Inspection and evaluation of carbeam trestles differs from that of typical steel beam bridges in that the anchorage of the beams and their bearing on timber caps is of critical importance for the integrity of the bridge.

The Inspector should check for evidence of steel beams cutting into timber caps. He should also note the condition of caps around anchor pins. Rot of the cap can make anchorage of carbeams ineffective. Inadequate anchorage can allow the beams to move longitudinally on the caps, losing their effective bearing.

c) Timber Caps – Since timber is weakest in compression perpendicular to the grain, it stands to reason that the most common evidence of deterioration of caps in crushing of the top of the cap under the stringer bearings or punching of piling into the underside of the cap. Just as pin connections through stringers allow for deterioration of the stringers due to rot, so too is the cap exposed to decay. The Inspector should check the top and bottom of the cap for evidence of crushing.

When a cap becomes hollow enough so that its ability to carry the compressive forces imposed by the pile tops and the stringers is no longer adequate, the sides of the cap may being to bulge out. The Inspector should sound the timber with a hammer to determine the extent of hollowing. **Condition 4: Cap sides beginning to bulge and/or piles punched into the underside of the cap.**

d) Timber Corbels – Corbels are short timbers usually found on multiple bents. When timber substructures support steel girder superstructures, the greater bearing loads of the long span girders require more bents than a conventional timber stringer span of twelve feet. Thus, two or three bent substructures may be required to provide sufficient bearing. Multiple bents differ from single bent construction in that they have corbel blocking bearing on the caps to support and spread the superstructure load to the entire multiple bent system.

Depending on the size of the bearing area provided by the girder and the configuration of the corbels (i.e. a single row of corbels in the direction of the span or a row of such corbels supporting transverse timbers in the form of a solid timber mat), all corbels or only some of the corbels may be taking load. As with other timber elements, the Inspector must check for decay and splits.

e) Cross Bracing – Timber piles on driven bents and timber posts on framed bents, resist sidesway and perform in unison by the application of timber cross bracing. The Inspector should check all fastening locations for evidence of decay or splits and checks which would render the cross bracing ineffective.

f) Longitudinal Bracing – The purpose of longitudinal bracing is to prevent movement of the trestle spans parallel with the track. Locomotive braking forces and driving forces (e.g. when train loads travel predominantly in one direction), may result in the trestle moving longitudinally. Evidence of such movement is particularly evident in out of plumb bents. Longitudinal bracing may be a series of horizontal timbers outside the stringer spans and attached to the ends of the caps, on a series of diagonal braces attached alternately to the top of one bent and to the bottom of the next bent. The Inspector should check for adequacy of bracing and evidence of bent or bents out of plumb.

g) Timber Sills – Sills are typically found where driven pile bents have been reconstructed as framed bents due to the extensive deterioration of piling at the ground line. Piles are cut off below the decayed portion and a sill anchored to the piling upon which a framed bent is constructed. As with caps, the sills are subjected to compressive forces due to the underlying cutoff piles as well as the timber posts of the framed bent. Problems may be encountered inspecting sills when they are under water or covered with surrounding soil. The exposure of the sills to alternate wet and dry conditions greatly increases the propensity to decay. The Inspector should make detailed notes of sill conditions as well as report circumstances when conditions prevent adequate inspection.

Sills found on mud blocking or solid timber mats should likewise be checked for decay. In addition, the general condition of the blocking or mat should be checked for adequacy of bearing and soil conditions.

h) Timber Piles/Posts – Timber piles transmit the loads from the cap into the ground either through direct bearing on rock or through skin friction between the pile shell and the soil. Piles are subjected to a combination of axial compressive loads and bending due to transverse and longitudinal forces and movement of the bents. Since the piles represent the primary support members of the bent, the Inspector should take great care in examining them for deterioration. Commonly, areas of the piling which have fastenings through them (e.g. at the connection to the caps, connections for cross braces and longitudinal bracing), are areas which should be inspected for mechanical wear and decay. Another area where alternative wetting and drying contributes to pile rot is at the ground line or the water line. The Inspector should sound the pile with a hammer for hollow areas. If extensive hollow areas are discovered through sounding, the Inspector should use an increment borer to test various segments of the pile. Sketches showing the location on the pile and remaining shell as determined through boring should be recorded. All holes introduced through boring or drilling should be resealed.

Timber posts on framed bents represent an additional problem due to lack of continuity from the cap into the ground. Timber posts must each be cut and fit squarely onto and adequately fastened to the sill in order to ensure even transmission of compressive forces from the superstructure bearings, through the bent and into the ground. As with piling, all posts should be checked for decay at fastening locations.

i) Bulkheads – The approach track ballast section and subgrade must be retained at each abutment of the timber trestle. For this purpose, timber bulkheads are constructed behind the abutment bents. The Inspector should check the timbers for soundness and any evidence of loss of ballast from the approach track structure.

j) Inspection of Repairs – Timber structures commonly reflect a wide variety of repairs from previous years. It is important for the Inspector to recognize the limiting parameters of such repairs.

1) Posting of outside piles shall not be permitted on bridges on curves where bents exceed twelve feet in height or on tangents where bents are over twenty feet in height.

2) On high speed track where traffic is heavy and not more than two posted piles in any one bent shall be permitted. If more than two piles are defective, all piles should be cut off to sound timber below the ground line and a framed bent installed.

3) All posts should be boxed, in addition to toe nailing, to prevent buckling or lateral displacement.

4) When individual caps, sills, braces or struts have become weakened beyond their ability to perform their intended function, they must be renewed.

5) When only an individual stringer is deteriorated, an additional stringer may be installed, inside or outside of the chord, to aid the weakened member.

6) Where piles are decayed at the top they may be cut off and double capped, a single pile may be corbelled.

7) Shimming of stringers to provide proper surface and cross level should be done with a single shim under each chord, if possible, avoid multiple shimming.

8) At all locations where repairs have been made, the Inspector should note the absence of protective treatment due to boring, adzing or cutting of the timbers.

X. SUBSTRUCTURES AND FOUNDATIONS

Substructures in this section deal with concrete, masonry and steel supporting elements (i.e. abutments and piers) which carry the loads imposed by the superstructures into the ground. Foundations refer to the natural supporting elements (i.e. rock, soil), their load bearing capacity and types of footings which ultimately support the entire bridge load.

In general, problems which the Inspector must be aware of with respect to inspection of substructures and foundations include subsidence and differential settlement, scour and undermining, deterioration of masonry pier and abutment stems due to loss of mortar between joints, lateral earth and surcharge loads on walls, loss of section and impact damage of steel supporting structures, cracks and deterioration of back walls, stems and bridge seats.

a) Foundations – The basic types of foundations used to support abutments and piers fall into two categories: pile type supports and footing type supports.

Piles (and caissons) support loads though the pile tips (and base of caissons) bearing on suitable rock or hardpan. Additionally, piles and pile groups may be supported by a combination of skin friction (utilizing the shear resistance of the surrounding soil) and direct bearing pressure on the soil at the pile tip. Piles may be of timber, steel or concrete. On Conrail, new trestle construction involves driving of steel pile bents. As with timber piles, steel piles should be checked at the ground line and where water levels fluctuate, as these will be areas which accelerate corrosion. Presence and effectiveness of protection systems (e.g. pile encasement) should be noted.

Footing type foundations generally involve a concrete or masonry spread footing on soil or rock. Such footings can either be a single, monolithic foundation under the entire abutment or pier stem, or individual spread footings such as are found under pier columns. Adequate bearing is dependent upon the shear strength of the underlying soil. In cases where the soil becomes saturated with water, it is possible for the footing to compress and punch into the soil, resulting in differential settlement of the substructure unit(s). Differential settlement of concrete and masonry substructure elements may be recognized by the appearance of cracks and displacement of concrete segments or stones. In steel substructures, differential settlement may be evidence by sheared rivet or bolt connections between columns and cross girders. The Inspector should identify any deficiencies which would indicate possible settlement, make reference marks for monitoring and observe the substructure under load for signs of movement.

For substructures located in water, the Inspector should take soundings to determine the waterway cross section under the bridge. A comparison with the channel cross section both upstream and downstream from the structure with the channel cross section under the spans of the bridge can be an indication of the hydraulic adequacy. Pronounced scour under the bridge may indicate the need for periodic underwater inspection. The determination of the need for underwater inspection should be made by the engineer using as criteria a combination of scour history, type of foundation and the nature of the streambed material upon which the substructure unit(s) are built. Underwater inspections are treated separately below.

b) Retaining Wall – Wingwalls are constructed at bridge abutments on either side of the track to retain the subgrade and track structure. These walls may be variously described as straight, flared or U walls, depending upon their orientation to the abutment. Such walls may be constructed of stone, concrete or timber (e.g. crib walls). Steel sheet piling and H-piling with timber or concrete lagging are special cases of retaining walls. The basic types of walls are described as gravity walls and cantilever walls.

Retaining walls must be designed to resist sliding and tipping (overturning) caused by lateral earth pressure and surcharge loads.

Gravity walls of stone or concrete depend upon their own weight for stability. These walls are stepped or battered on the rear face.

Reinforced concrete cantilever walls depend on a combination of their own weight and the weight of the soil backfill bearing on the footing to provide stability. Such walls, in comparison to gravity walls, have thin stems and rely upon steel reinforcement to resist the imposed loads. Steel sheet pile walls and H-pile walls with timber or concrete tagging are special cases of cantilever walls.

The Inspector should inspect the retaining wall for defects and deficiencies in the material (e.g. decay of timbers, corrosion of steel, cracks in stone and concrete, displacement of wall stones, open mortar joints and water seepage). Significant defects should be accurately referenced and documented. Depending upon the nature of the defect, the Inspector should try to determine the cause (e.g. differential settlement, overturning, ineffectiveness of tiebacks) and include this in his report for engineer's review.

c) Abutments – Abutments can be considered a special case of retaining wall. In addition to retaining the earth fill and track subgrade behind the abutment stem, the abutment provides support for the superstructure bearings at each end of the bridge. Abutments are designed to resist both vertical and horizontal forces.

1) Backwalls should be checked for adequacy in retaining the approach track. Loss of subgrade or ballast through a damaged or failed backwall can result in a depression in the track structure. Cracks in concrete or stone backwalls, displacement of backwall stones should be referenced and documented.

2) Bridge seats supporting the superstructure bearings may be either concrete or stone. As described in Section VI (a) 3, the effective bearing area provided by the masonry plate on the bridge seat is dependent on the compressive strength of the bridge seat material and the thickness of the masonry plate. Inadequate bearing area will result in the superstructure bearings punching into the bridge seat with consequent pumping of the girder or stringer. Over a period of time, such pumping action can lead to further deterioration of the bridge seat by initiating cracks in the concrete or stone.

3) The abutment stem should be checked by the Inspector for signs of differential settlement which may be indicated by significant cracks and/or displacement of concrete or stone. Settlement may be the result of a single event (e.g. undermining during flooding conditions) which has since stabilized and shows no recent change, or may be an active and continuing problem. It is important for the Inspector to reference and document all cases of settlement for monitoring, regardless of how old the condition may be. The engineer can be of assistance in researching the history of the settlement and any previous repairs.

The Inspector should also check for the presence and adequacy of drains or weep holes. Plugged drains and weep holes can retain water behind the abutment allow water to seep through the abutment between stone mortar joints or through concrete construction joints. Such seepage leads to deterioration through freeze/thaw cycles, cracking stones and concrete. In addition, lack of mortar between stones results in loss of even bearing pressures and can accelerate cracking of stones due to point loads.

d) Piers – While some components of piers have the same characteristics as abutments for the purpose of inspection (e.g. bearing seats, stems and footings), piers differ from abutments in that they support superstructure bearings from two spans and are not designed to retain fill or embankment material. Piers supporting bridges over waterways, in addition to being susceptible to scour, are also subject to damage from floating debris, collision damage and ice loads.

e) Towers – Steel towers represent particular problems for inspection due to their height and size. Superstructure loads may be transferred through cross girders into the tower columns. An inspection of girder to column connections is essential. As with any compression member, tower columns rely upon intermediate bracing to resist the tendency for buckling. The Inspector must check all bracing and bracing connections to the columns. Columns should be inspected for signs of corrosion and reduction.

f) Underwater Inspection – There are basically two modes of underwater inspection: probing to determine presence of scour (and the extent, if any, of undermining of substructure elements) and diving inspection.

Prior to conducting the underwater inspection, the general condition of the waterway should be noted. Evidence of prior high water conditions such as erosion of stream banks or changes in water course may indicate significant changes in the scour characteristics at the bridge since the last inspection. Accumulated drift should be noted with a description of its extent and location. Drift accumulation at substructure components can reduce the effective channel width leading to local increase in water velocity which may cause scour action. Drift also poses a fire hazard.

Probing to determine streambed cross sections and extent of scour around piers and abutments can be best accomplished with sounding rods, although plumb lines and electronic depth finders may be sufficient in some cases. The Inspector should consult the previous inspection report to compare the location and depth of scour with current conditions. When probing around abutments and piers, the Inspector should probe carefully along the entire stem to detect evidence of undermining of the footings. All sounding depths should be recorded. The Inspector should note the presence and condition of any scour protection such as sheet piling or rip rap. Sounding information must be recorded on Form MW 206.

Diving inspections should be conducted when it is determined by the engineer, based on a combination of factors relating to history of scour/undermining and the type of foundation and condition of the substructure, to be necessary. Diving inspections will be conducted under the supervision of a Professional Engineer and according to Conrail Specifications for Diving Inspections. A copy of the diving inspection should be available for future reference.

XI. MOVABLE BRIDGES

Movable bridges are built to accommodate marine traffic and, in addition to the movable span itself, usually consist also of a series of fixed approach spans. Regardless of movable span type, all of the structural inspection concepts which apply to fixed bridges also apply to movable bridges. The Inspector must also be aware of additional inspection concepts involving bridge component stresses and problem areas associated with and unique to the movement of the bridge, as well as inspection items relating to machinery and other operating components, electrical controls (e.g. limit switches), dead load vs. live load bearings, fender systems and navigation lighting.

This instruction is not designed to cover all aspects of movable bridge inspection in detail. An inspection program must be designed for each movable bridge to ensure that all relevant components unique to each bridge are being properly inspected. A check list of inspection items should be kept by the Inspector to ensure continuity of inspection. A movable bridge inspection (distinct from a structural inspection which is required semi-annually) must be conducted at least quarterly involving specialists from all maintenance departments to rate conditions unique to the bridge operation. A test opening of the movable bridge is essential during the course of the inspection for observation of moving components and to test the electrical system. Conditions of components inspected during the quarterly inspection must be recorded on Form MW 205.

More frequent maintenance inspections of various components may be required by the engineer for items subject to rapid change or for items which present recurring problems such as bolted connections associated with the miter rails, bridge seat cleanliness during inclement weather which could affect limit switches, etc.

The following is a brief description of several of the items which must be included in a quarterly movable bridge inspection program.

a) The Track – Common to all operable movable bridges is the discontinuity of the track structure represented by miter rails which allow the movable span to open. Miter rails must have good bearing in tie plates and miter rail casting plates in order to prevent excessive movement which could result in rail end batter and/or broken rails. The Inspector should examine the ball of the rail for signs of batter. He should inspect the base of the rail to ensure that it has full bearing in tie plates and in the miter rail casting plates. In addition, all bolted connections of web plates and rail guides should be checked for signs of distress (e.g. broken bolts, misalignment).

Timber head blocks should be inspected for wear and adequate connection of miter rail castings. Bridge ties at the jointed end of the miter rails should also be checked; excessive movement at the jointed end of the rail can accelerate rail end batter or cause cracks in the miter rail.

Miter rail gaps should be measured and recorded along with the temperature at the time of the measurement. During hot weather, closed miter rail gaps can present problems of reseating after a bridge opening. During cold weather, too large a gap can contribute to rail end batter.

Miter rails should be observed during the test opening for alignment and reseating.

b) Bearings – The Inspector should check the bridge bearings to determine that the movable span is properly seated and live loads are transmitted fully and evenly to the rest piers(s). The bridge seat must be free of debris, drift or ice which could prevent proper seating of the bridge or foul shock absorbing buffers or limit switches.

c) Lubrication – There are numerous locations on movable bridges requiring regular lubrication. A checklist of all areas unique to the bridge should be kept by the Inspector and adequacy of lubrication noted for each area during the quarterly inspection. Recommendations for more frequent lubrications may be based on the quarterly inspection findings.

d) Limit Switches – Of vital importance in controlling the operation of the movable bridge, all limit switches should be inspected to determine that they are functioning as designed. Failure of limit switches can result in service interruptions as well as lead to damage of their operating components of the bridge.

e) Electrical System – The electrical system should be thoroughly checked by qualified electrical department personnel. Amperage readings should be made during the test opening to determine whether the system is operating as designed. High amperage readings may indicate a problem involving obstruction or fouling of a bridge component which could lead to an operational failure.

In addition to the primary power supply, the back-up power should be checked. Test openings using both primary and back-up power systems should be conducted. The transfer switch should be checked to determine whether it is operating properly. Fuel tanks for back-up generators should be inspected to ensure sufficient fuel is available for stand-by operation.

f) Navigation Lights – Navigation lights should be checked for proper location and operation. Navigation lighting must be maintained in accordance with U.S. Coast Guard requirements for Bridge Lighting and Other Signals according to the U.S.C.G. Bridge Administration Manual.

g) Fender System – While complete inspection of the fender system will invariably involve a diving inspection, the Inspector should note any obvious defects associated with the fender. Such defects include the presence of fire damage, rotted or missing timbers, evidence of impact damage, movement evident in the wake of marine traffic which may indicate damage below the waterline.

XII. TUNNELS

There are basically two types of tunnels: 1) tunnels “holed” through rock, which may be lined or unlined and 2) tunnels with shallow cover in soft ground which have been constructed by the cut and cover method. The importance in distinguishing between the two for the purposes of inspection resides with the likely problems encountered which are unique to the two situations.

a) Tunnels in Rock – Depending upon the nature of the rock, tunnels may or may not require lining. In many cases, tunnels may have sections which are lined as well as unlined. Rock in tunnels is affected by its own weight as well as the weight of the overburden above it. Just as in any other material, stresses develop in the rock due to the loads imposed on it. The bridging capacity of rock depends on the type of rock and its shearing strength. In some cases, a natural rock strata of a tunnel roof which is unstable (e.g. layered, sedimentary rock) may be stabilized by the installation of roof bolts. These bolts project through the unstable layer into firm rock, binding the rock strata together.

For rock with low bridging capacity, in fault zones where rock is shattered and unstable and in areas with significant water infiltration, tunnels may be lined with stone or concrete. The space between the lining and the natural rock is packed with fill material such as stone or concrete to provide support for the natural rock and redistribute shearing stresses around the tunnel opening. This effect is known as arching. The same arching phenomenon is at work in unlined tunnels, the only difference being that the bridging capacity of the rock is sufficient to support itself without the assistance of a liner.

b) Tunnels in Soft Ground – Shallow tunnels in soft ground may be constructed through soil boring techniques using shields or by cut and cover methods. The key difference between these tunnels and those bored through rock is the relatively weak shearing and tensile strength of the soil as compared to rock. This means that the entire tunnel is dependent upon a lining for its integrity.

The Inspector should review with the Engineer the plans and other documentation concerning the tunnel to understand the nature of the liner construction, the foundation material and type of footing of the lining, drainage design for the tunnel and presence and importance of tunnel invert. The Inspector should be aware of the problems of vertical and lateral earth pressures against tunnel linings. The Inspector should be aware that undercutting of track and deepening of drainage ditches can serve to undermine the integrity of liner footings, causing shear failure of the underlying foundation material. The Inspector should note and report to the engineer any evidence of track misalignment or evidence of soil heaving in the tunnel.

c) Inspection – The Inspector should arrange to inspect tunnels during extreme seasonal conditions. Results of tunnel inspections must be documented on Form MW 207.

In the winter, the Inspector should note the presence of ice build up at the portals and the effects of icicles projecting through tunnel linings. Ice build up in tunnels can destroy, over a period of time, sections of lining, as well as create clearance problems for passage of trains. Ice build up in the track structure can heave or distort the track. In natural rock sections, water infiltration through fissures in the rock may result in freezing during extremely cold weather with resultant prying loose of rock layers.

In the spring, the Inspector should inspect all areas of water infiltration through the lining. Drainage ditches should be inspected for adequacy of flow. If drainage pipes and/or pumps are present, the Inspector should determine whether the drainage system is operating properly to carry water away from the track structure.