EXTENDING THE SERVICE LIFE OF TIMBER RAILWAY BRIDGES

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ABSTRACT

Times of downturn in economy, tough competition, high costs, and large amounts of capital required for replacements have created growing need for cost cutting measures and for seeking better return on investment. This has also placed an increasing emphasis on maintenance practices to extend the service life of existing railroad bridges.

This paper outlines the various factors which play a role in the degradation of timber bridges and the measures that are necessary to effectively extend the usefulness of such bridges. Method of evaluating the residual capacity and categorizing maintenance into preventive, early remedial and major are discussed.

The paper concludes that railroad bridges are cost-effective structures whose service life could be prolonged significantly by timely and proper maintenance provided that they were adequately designed and constructed.

INTRODUCTION

A well designed and constructed timber bridge (i.e. trestle) has been known to give more than 60 years of relatively maintenance free service. In North America railroad timber bridges represent low initial cost, ease and expedient construction, and ease of maintenance. They are capable of supporting short term overloads without adverse effects and possess better resistance to corrosive environment. They also present a pleasing appearance in natural setting (see Figure: 1).

According to a recent survey (Bulletin 1), timber trestles represent approximately 43% of the railroad bridge inventory in the United States and Canada. Although, they have served the mainlines for many decades, their use now seems more predominant on secondary and branch lines.

Deregulatory moves have created an atmosphere of tough competition amongst different modes of transportation in North America. The result is that the railroad industry which traditionally had higher operating costs, cannot afford to raise large amounts of capital required for plant replacement and thus must find new measures of cost reduction for their survival. Extending the service life of existing trestles is only one of such measures some railroads are employing.

PROPERTIES OF WOOD

To be able to thoroughly inspect and properly evaluate the condition of a trestle, one must understand the basic properties of wood, the agents that cause it to deteriorate and the ways to prevent its deterioration in service. Wood is an anisotropic material. Its structural properties depend on numerous factors; such as; species, micro structure, moisture content, growth defects, temperature and rate, duration and direction of loading etc. Wood has a cellular micro structure. Wood cells are long, slender, and like hollow tubes, 90 to 95% of which are lined in longitudinal direction. The cell walls are composed of cellulose, hemicellulose and lignin. Wood is also hygroscopic. It absorbs moisture from the atmosphere when it is dry and releases it to the atmosphere when wet to keep it in equilibrium with its surrounding. Green wood may have a moisture content as high as 200%. As it dries, water in the cell cavities, the free water, escapes. Once all the free water has escaped the wood reaches its fibre saturation point (FSP) at a moisture content of 30%. No dimensional changes occur in wood up to this point. However, when the moisture content drops below FSP, water in the cell walls, bonded water, starts to escape. When this happens, the wood shrinks and its physical properties change. Its strength in compression,
shear and bending as well as its modulus of elasticity increase while its toughness decreases with an increase in moisture content. Shrinkage causes wood to check and split particularly if its rate is not controlled. The shrinkage is greatest along its tangential axis, followed by the radial axis and is the least occurring along its longitudinal axis. For Douglas Fir, the allowable stress in bending is about 130%, in compression perpendicular to grains is about 60%, in axial tension is 80% and in shear is about 8% of its strength in compression parallel to grains. The permeability of water along the grains is 50 to 100 times greater than its permeability across grains.

Wood may exhibit elastic behaviour up to or very close to its failure depending upon the property in question. For all practical purposes Douglas Fir can be considered elastic within the range of working stress.

Temperature changes affect the wood properties at a given moisture content. Its strength decreases with increase in temperature and long periods of exposure. At low temperatures accompanied by high moisture content, the strength of wood decreases.

Unlike other materials, wood can resist substantially greater loads for short durations than for long periods. For loads of relatively short duration, wood deflects elastically and recovers to its original state when load is removed. For sustained loads, wood would undergo additional time-dependent deflection known as creep, which would not recover upon removal of the load.

**AGENTS OF DETERIORATION**

Wood would last for centuries if it is kept dry and away from hazards. However, in an unprotected environment, wood will be subject to attack by biotic and physical agents capable of degrading the wood structure (Ritter").

a) **BIOTIC AGENTS:** They are living agents such as decay fungi, bacteria, insects, and marine borers present the greatest hazards to the timber bridges. Bacteria colonize in very wet environments, causing increased permeability and softening of the surface of untreated wood. Fungi are simple plant like organisms that breakdown and utilize wood material as a food source. They move through the wood as a network of microscopic threadlike hyphae that grows through the pits or directly penetrates the wood cell wall. As hyphae elongate, they secrete enzymes that degrade cellulose, hemicellulose and lignin and absorb the degraded material to complete the digestion process. Fruiting bodies produce millions of spores which germinate into fungi are widely spread by wind, insects, and other means and can be found on most exposed surfaces. There are the mould fungi, the stain fungi and the decay fungi. The decay fungi are further grouped into the manner in which they attack. The wood attacked by the Brown Decay Fungi looks brownish with cross-checks and is brittle, by the White Decay Fungi is whitish or light tannish and the Soft Rot Fungi is wet and soft on the outer shell. All fungal damage causes wood to lose its weight and strength (see Figure: 2). Insects that cause most damage to wood are; Termites, Beetles, and Bees, and Wasps and Ants. Their attack is evident from tunnels or cavities in wood which contain wood powder or frass and their damage causes wood to lose weight and strength. Termites species associated with wood damage are the Subterranean that nest in moist ground and whose tunnels are filled with frass and debris, the Dampwood that nest in very wet wood and make large tunnels containing pellet like frass, and the Drywood termites which attack drywood. Beetles are the largest order of insects and contain nine families which cause substantial damage to wood. They tunnel wood for shelter and food and cause damage in the form of powder posting, pin or grub holes and stains. Ants, Bees and Wasps also represent several different species. The most common are the Carpenter Ants and the Carpenter Bees that use wood for shelter and for rearing their young. Their damage is characterized by clean and frass free tunnels. Marine Borers cause severe damage to wood. They are classified into three groups; namely Pholads, Shipworm and Limnoria. Pholads are clamlike mollusks that burrow into wood and filter food from the surrounding water and damage wood near the surface. They are very active in tropical environments. Shipworms are long wormlike mollusks which cause interior damage to wood. Their free swimming larvae settle down to wood where they grow and their tunnels extend throughout the cross-section. Limnoria or gribbles are mobile crustaceous that differ from shipworms and pholads in that they move from one piece of wood to another during their life cycle. Limnoria damage wood by burrowing small diameter tunnels near wood surface.

Most of biotic agents that enter and decay untreated wood require the following four basic conditions for survival. The absence of any one of them, would render the wood safe from biotic attack.

1. **Moisture:** Although some fungi and insects can attack wood at much lower moisture contents, wood below the fibre saturation point (FSP = 30% m.c.) generally does not decay. At higher moisture content contents the

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cellulose swells and is more accessible to fungal enzymes enhancing the rate of decay. Repeated wetting and drying causes leaching of heartwood extractives and preservatives thus reducing the natural resistance of wood to decay.

2. Oxygen: Most fungi can survive at very low oxygen, but, all of them require some oxygen for respiration. For example, the untreated piling will decay to waterline, but would remain sound underwater where oxygen is absent. Similarly piling which is totally submerged or placed below the water table will not rot.

3. Temperature: The temperature at which the activity of the biotic agents is optimum ranges between 20 to 30°C. However they are capable of surviving over a considerably wider range. Below 0°C, their activity slows down or they become dormant. At temperatures of 0°C or greater, they begin to attack wood and their activity grows as the temperature increases. As it approaches 32°C, the growth starts to decline again but could continue till 40°C. A 75 minutes of exposure at about 65°C will eliminate all decay fungi established in wood. Decay is more serious in warmer climates with rainfalls where the rate of biological activity is also higher.

4. Food: Most biotic agents use wood as a food source while other use it for nesting. Most wood species have certain degree of natural resistance to decay but this is reduced rapidly by weathering and leaching. When wood is treated with preservatives, food source is poisoned. The infestation then can occur only where preservative treatment envelope is inadequate or has been broken. Maintaining an effective preservative treatment is very crucial for preventing wood from biotic attack. To adequately protect wood, preservative must have toxicity to intended target, the ability to penetrate the wood and to persist in sufficient quantities for long periods. The degree of protection would depend on the type of preservative used, the treatment process, the species of wood, and the environment to which the structure will be exposed. Based on the chemical composition and type of solvent or carrier employed, wood preservatives are broadly classified as Oilborne and Waterborne. The three oilborne preservatives used in bridge applications are Coal-tar Creosote (creosote), Pentachlorophenol (penta) and Copper Naphthenate. The waterborne preservatives include formulations of inorganic arsenical compounds in a water solution such as Chromated copper arsenate (CCA), Amoniacal cooper arsenate (ACA) and Amoniacal copper zinc arsenate (ACZA). A preservative may be applied by non-pressure method such as brushing, soaking, dipping, diffusion or by pressure method full-cell or empty-cell process which involves combination of vacuum and pressure in a confined cylinder, as the end use demands.

b) PHYSICAL AGENTS: Are non-living agents that can become serious in specific instances such as traffic, stream flows, soils, weather, or other conditions. The physical agents can also damage the preservative treatment, exposing untreated wood to attack by biotic agents.

1. Traffic: The mechanical damage from a derailment, collision, or impact of falling or abrasion of dragging objects, ice, brush and debris in flow, could damage and weaken bridge components. The dynamic effect of trains, particularly the unit trains which could set up resonant condition at certain speed and could cause excessive displacement, shifting of components or jack-knifing of multi-storey bents. The long term exposure to overloads may cause crushing or cracking in wood.

2. Stream Flows: Damage resulting form flow may include erosion of banks, scour, and undermining of foundations and washouts. Drift or material from failed beaver dams, ice can accumulate against relatively small openings of some bridges and cause considerable damage including dislodging of bents unless periodic cleaning is done or protection is provided. Wood is quite resistant to mild acids and alkalies present in flows. Normally strong acids and alkalies do not come in contact with a timber bridge unless an accidental spill occurs but could cause serious damage to wood cells.

3. Soils: Shifting, unstable embankment and earth slides in the proximity may cause movement and damage to bridge components. Piles driven through weak strata may lack in lateral stability and sway under traffic. Piles driven with inadequate penetration or subject to overloads can settle differentially or move vertically affecting line and surface of track on the bridge.

4. Weather: Regions of heavy rainfall and warm temperatures present ideal conditions for the growth of and attack by biotic agents as opposed to regions with frigid and arid climates. Thus bridges located in areas having low rainfalls (i.e. less than 635mm per year) or short growing seasons have a reduced potential for decay. Temperature variations also affect moisture content. Wet and dry cycles tend to leach out the extractives from

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wood and cause wood to check and split due to shrinkage. Use of oil type preservatives retard moisture movement to and from wood thereby reducing checking. Sub-zero temperatures may cause frost jacking of piles, particularly when there is insufficient penetration of piles. Differential frost jacking of piles makes it difficult to maintain track geometry.

The ultraviolet portion of sunlight chemically degrades the lignin in the outer shell of the wood and weakens it slightly. Strong winds affect the lateral stability of high trestles. The old timber bridge at Uno, Manitoba was completely destroyed in 1915 by a storm (see Figure: 3).

5. Corrosion: It begins when moisture in wood reacts with iron in a fastener to release ferric ions that in turn deteriorate wood cell walls. As corrosion progresses, the fastener becomes an electrolytic cell with acidic end as anode and alkaline end as cathode. The anode causes cellulose hydrolysis and severely reduces the wood strength in the affected zone. The damage by metal corrosion can be limited by using galvanized or non-iron fasteners.

6. Fire: Despite the fact that wood is a good heat insulator and in heavy sizes would resist fire, it is a combustible material and thus is susceptible to damage or loss by fire. Fire could start from bridge deck, by a dropped fusee or burnt brake shoe, from ground as grass fire or it could be caused by an accident such as a derailment, collision or lightning or it could be due to an act of carelessness or vandalism. The damage depends on the location and the extent of burned wood.

7. Work Practices: To accommodate grade raises in track, ballast may be added to bridge decks or decks may be lifted by means of shim blocks. Ballast in excess of that allowed by design could reduce the trestle capacity. Thin shims (under tie-plates, stringers, caps and piles etc.) should be avoided if at all possible, as they could retain moisture and cause looseness and rot in the components.

Frequent spiking during rail relays can render the ties "spike-killed". Use of rail fasteners that would not require their removal for changing rails would help solve this problem. Edging ties affects the protective treatment, thus enhancing the possibility of an early decay.

A bridge span is substantially stiffer than a piece of track. The bridge approach is intended to provide a smooth transition between the two. An approach cannot fulfil this requirement if it is low or lacks the appropriate amount of ballast. The deficiencies result in the spans adjacent to the approach subject to impacts.

**DETECTION OF DECAY**

Wood decay occurs when proper conditions prevail for the growth of fungi, insects and other biotic agents. Decay in wood can be classified into the following three stages (see Figure: 4): (1) Incipient Decay: is the newest part of infection when no visible signs of attack exists and the damage is difficult to detect, (2) Intermediate Decay: is when wood becomes softened, discoloured and retains little if any strength, and (3) Advanced Decay: is when wood retains virtually no strength and decay pockets or voids are formed or wood is literally dissolved. In general, the detection of decay can be divided into the exterior and the interior decay detection.

(1) EXTERIOR DECAY: This is easier because it is often readily accessible to inspector. Two methods used are namely: Visual Examination, and Probing.

(a) Visual Examination: This involves examining the trestle for signs of actual or potential decay and noting the areas for further investigation. Some of the common visual indicators of decay are as follows: (i) Fruiting Bodies: which provide a positive indication of decay but they do not tell the amount or the extent of decay. (ii) Sunken Faces: these are localized surface depressions which can indicate underlying decay. Decay voids or pockets may develop close to the surface of a member but remain obscure due to thin, depressed layer of wood at the surface. (iii) Staining or Discolouration: this indicates that a member has been subjected to water and has potentially high moisture content suitable for decay. Rust stains from connection hardware are also indicative of wetting. (iv) Insect Activity: is characterized by holes, frass, powder posting or other signs and may indicate the presence of decay. (v) Plant or Moss Growth: this type of growth in splits, cracks or soil accumulations on the members indicate that the wood has been at a relatively high moisture content for sustained period of time and may be suitable for decay.

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(b) Probing: Probing is simple and widely used method. A pointed tool such as an awl, knife, screwdriver or pick is used to drive into wood or pry out sliver from wood. The excessive softness or the ease of probe penetration provides indication of decay. Care must be taken to differentiate between decay and water softened wood that may be sound but softer than drywood. Similarly a splintered break of fibrous nature is the sign of sound wood and a brash and abrupt break across gains or crumbling is the sign of decayed wood. Pliodyn which is a spring loaded pin device that drives a steel pin into wood is also used to detect surface damage. The depth of penetration is used as a measure of the degree of decay.

(2) INTERIOR DECAY: Interior decay is difficult to locate because there may be no visible signs of its presence. Several methods to detect the internal damage are available from simple sounding to sophisticated radiography. Some of the commonly used methods include:

(a) Sounding: Striking wood with a hammer or other object is one of the most commonly used inspection methods for detecting interior deterioration. Based on the tonal quality of the ensuing sounds, a trained inspector can interpret dull, hollow or echo sounds that would indicate the presence of large interior decay, void, or sound wood respectively. When suspected decay is encountered, it must be verified by other methods such as boring or coring.

(b) Moisture Meters: When decay occurs, certain electrolytes are released and alter electrical properties of wood. Based on this phenomenon, several tools for detecting decay hazard have been developed. These tools require correction for temperature. They do not detect decay but simply help identify high moisture content. At 30% or more moisture content conditions are ripe for decay to start.

(c) Shigometer: This instrument uses a pulsed current to measure changes in electrical conductivity associated with decay. A small hole is drilled, a twisted wire probe connected to a meter is inserted into the hole. As probe encounters zone of decreased resistance, the meter reading drops. Shigometer has worked well in detecting decay in trees but wood in service is too dry to make use of it.

(d) Drilling and Coring: Both techniques are used to detect the presence of decay and voids and to determine the thickness of the residual sound wood. A power drill or a hand crank drill with a 10 to 20mm bit is used to drill into members and to note zones where drilling becomes easier or has no resistance due to softness or void and to observe the shavings for wetness, and change in colour due to decay. For coring, an increment borer is used to find decay pockets and other voids, depth of preservative penetration and evidence of decay. Drilling and coring methods are assisted by use of a shell-depth indicator (poker) which is a graduated metal rod with a hook at one end which is inserted into the inspection hole and pulled back on the hole sides. Hook moves with some resistance in holes with decay and catches on the edges of voids. An experienced inspector can identify the depth of a void, decayed and solid wood, which could be used to estimate the strength of the residual wood.

(e) Sonic Evaluation: Different sonic tests for evaluating the condition of wood have been developed in recent years. These are Sonic Wave Velocity, Acoustic Emission, and Stress Wave Analysis etc. The simplest method is based on the change of the velocity of a sound wave moving through wood. The altered sonic wave can be used to determine the exact size and nature of a defect.

(f) X-Ray and Tomography Scanner: This method is based on the principle that as an x-ray passes through wood, the presence of knots or other defects alter the density of resulting radiograph. This method is expensive and requires an expert to interpret the radiograph. Recently computer aided tomography scanners have been developed for wood poles which give an image of internal wood condition.

METHOD OF INSPECTION

The inspection of a wood bridge (Training Manual3) should be undertaken systematically, that is, working from the top of the superstructure to the lowest part of the substructure and its the surrounding or the in reverse order. The inspector must thoroughly examine the trestle for decay and other form of deterioration. The behaviour under the movement of trains should be observed where possible to evaluate the overall riding quality and integrity of the bridge and for any signs of excessive distress, crushing, deformation, sway, vertical movement of piles, jack-knifing or looseness of joints, indication of water forcing out of interface locations or other abnormal conditions. The inspector should record his findings in sufficient details to enable engineers to make an engineering appraisal.

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The inspection process could be divided into the following three basic steps:

1. **PRE-INSPECTION ASSESSMENT:** This involves a preliminary assessment of the condition by review of all available information from the previous inspection reports and other records such as design, construction, repairs and maintenance, changes in traffic or loads, decay and damage history, potential of environmental hazard and climatic and flow data. Information from people who are familiar with the bridge and its surrounding to gather any information on past history and problems.

2. **FIELD INSPECTION:** This involves the physical examination of the trestle for evidence of deterioration. Inspector must know the basic properties of wood, the agents of deterioration, and the techniques of detection of decay and other forms of deterioration. He must be qualified in railway operating rules and be trained in the proper use of tools required for inspection and for his personal and railway operational safety. In addition, he must be able to identify, locate and accurately define the degree and the extent of deterioration and be able to appreciate its effect on the bridge traffic carrying ability.

The areas commonly susceptible to decay are the areas where wood-moisture is high indicated by signs of water marks, staining or light mud stains, where break in the preservative envelope resulting form mechanical damage, overloads, abrasion, and settlement provides an entry point for decay organisms, around fasteners, checks, mechanical damage and interfaces. The bridge moisture conditions are not only subject to seasonal variation but also occur in localized areas such as horizontal surfaces, contact areas, depressions or other features that may trap water. The potential of decay in untreated wood and seasoning checks is quite high.

The Field inspection may be divided into the following steps:

(a) **General Survey:** This involves a brief walk across and around the bridge, observing general features, components for overall integrity and for obvious signs of deterioration or distress, track alignment and surface, straightness of walkway railings, plumbness of bents and piles, drainage and stability of river banks and approach embankments etc.

(b) **Superstructure Inspection:** The components above caps (or above other deck support), such as spans, deck, track, and walkways etc. Use of ladder, suspended scaffolding or heavy equipment such as the Snoop may be necessary for inspecting underneath of superstructure. The decay is suspected in checks, crevices, bearing areas and member interfaces where air circulation and the drying process is inhibited.

(c) **Substructure Inspection:** The components from caps down to ground (or below ground if suspected) - such as soil contacting members, posts, sills, piles, dumpwalls, braces, tie-rods and connections etc. Look for the presence of vegetation and decayed wood nearby. The dumpwalls that show signs of breaking or bulging from earth pressure. The horizontal surfaces of caps that trap debris and water from deck and allow it to enter into fastener holes of caps thus cause decay and crushing under loads. The substructure in water is difficult to inspect. The under-water inspection requires high degree of skill. The timber in seawater should be inspected at low tide, for marine boron damage. Limnoria attacks external faces of members, a scraper and probe to be used for removing fouling organism. Hourglass shape of piles in tidal zones, boreholes, general softening of wood are the typical signs of marine damage.

All components of a trestle should be systematically examined. When decay is found, its location and extent must be noted so the load capacity of the individual members can be determined (see Figure: 5). At some locations the deterioration may have a very little effect while at other locations, a small decay would reduce capacity significantly. Most important is the sequence and coordination of inspection efforts. To ensure all the critical areas are covered, a well defined plan must be instituted.

(3) **PREPARATION OF REPORT:** An inspection report should be well organized, clear and concise and should include sketches, drawings and photos etc. as necessary to elaborate the findings. When inspection is completed all information should be accurately recorded before leaving the site. The report should meet the following objectives: 1) identify weaknesses or deficiencies which would limit the capacity of the bridge or otherwise make it unsafe for regular traffic; 2) provide a chronological record of the condition and the information necessary to do a structural appraisal if required; 3) provide a basis for identifying current and future maintenance and upgrading needs through record of defects or deficiencies, and 4) serve as a reference source for future inspections and
comparative analyses.

EVALUATION

The strength loss due to decay depends on the area of infection and the stage to which the decay has developed weather advanced, intermediate or incipient. Since it is difficult to clearly define the extent and severity of decay, the safest approach is that no strength value be assigned to wood showing evidence of decay regardless of the stage of its development. Such estimate is also appropriate because the decay would generally continue to reduce strength further unless maintenance actions have been taken to arrest its growth (Muchmore 4). The outline of the remaining sound wood both in cross-section as well as in length could be represented by convenient geometric forms for computing the residual capacity of the affected members. Once the capacity of the individual member is determined from the decay and other forms of deterioration, it could then be compared with the railroad’s acceptable standards. This information then is adjusted for other factors such as age, past and future maintenance and the expected load and traffic requirements etc. The evaluation of the entire bridge is made for its overall capacity as well as for its integrity under traffic. The key element of the evaluation process is not only to identify the nature of maintenance required but also its timing that would yield the most cost effective results in terms of extending the service life of the bridge.

EXTENDING THE SERVICE LIFE

A maintenance program developed on the basis of a system of effective inspections and followed by careful evaluations represents a strategy that improves the safety of operations and extends the service life of the trestles. In turn this approach reduces the frequency and the expense of costly repairs. Program objectives should be not only to fix the existing deficiencies but also to take proactive measures to prevent or reduce the future problems. Unfortunately, short term gains, budgetary constraints and apparently high profile issues often prevail over the necessity of timely and proper maintenance. Such maintenance could substantially reduce the long term costs, frequently neglected until critical problems develop that require major repairs or replacement of the bridge.

The maintenance comprises those activities which are necessary to preserve the usefulness of a bridge and ensures the safety of its regular service. In practice, these activities can be divided into three categories: namely preventive, early remedial and major maintenance.

1. PREVENTIVE MAINTENANCE:

The deterioration has not started, but the conditions conducive to decay or damage are present and maintenance is required to prevent deterioration. The activities may include:

a) Moisture Control: This is the most economical and practical method for extending the service life of timber bridges. The most effective approach is to locate the source of moisture and to take corrective action to eliminate it. If this is not feasible, prevent the exposure and infiltration of moisture to the wood by application of moisture proof coatings such as bitumen overlaid with rolled roofing material at the end grain area such as top of piles and posts, joint sealants and filling compounds in exposed horizontal surfaces and impervious membranes such as heavy plastic or neoprene between deck and stringer chords. Similarly, the entry of moisture in wood through areas which have suffered the loss of treatment envelope due to mechanical damage, dapping, framing and edzing etc. can be prevented by mopping or spraying the preservative over the affected areas.

b) Fire Control: Maintenance includes keeping the timber bridge and its immediate proximity clear of grass, brush or other combustible material. Keeping the bridge members clean and free of frayed fibres. Taking extra precautions while using a flame torch, rail slitter, rail welder or other tools involving spark or flame about a bridge would help prevent fire damage. Other measures which would reduce the risk of fire damage are provisions such as fire-breaks, fire-walls, conversion of an open to a ballast deck, use of concrete caps, intermittent use of concrete deck slabs or use of some fire retardant coatings.

c) Periodic Stream Cleaning: Debris and brush may accumulate against the bents of some trestles which could damage the bridge, its banks and the adjoining property. Stumps of old piles present hinderance to flow and navigation. Old pile stumps are often infested and can transport decay organisms to good wood of the bridge thus spurring early start of decay. To prevent decay transfer the old piles should be cut down to the stream bed level

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or below the ground level and covered with earth. Adequate protection against erosion of soil and floating ice and logs should be provided.

d) Control of Excessive Impact and Vibrations: Ties, stringers, caps, posts and piles are designed to have uniform bearing on their supports and to have sufficient flexibility to undergo the necessary deformation under live loads. Neoprene or other cushioning pads may be employed to take care of minor misfits of members. However when the members are twisted, sunk or frost jacked and not properly bearing, they should be corrected immediately to avoid prolonged overstress of the other members in the bridge. Fasteners require tightening after a couple of years of construction, and at periodic intervals thereafter, for ensuring the proper working of the components. Dumpwalls are often raised to suit the lifts in track. As they are only designed to retain a given depth of backfill, they must be reinforced for any added height of fill.

e) Miscellaneous Practices: Always keep the bridge clean. A tidy bridge site is usually free from common hazards. A low bridge approach and the one with poor ballast section does not provide the desired transition zone. This causes high impact at the ends of bridge spans, unnecessarily adding to maintenance problems. Provide full ballast sections at the bridge approaches. Rails should not be supported directly on dumpwalls which are designed to retain the ballast only. There should always be a gap and no contact between it and the bases of rails. As far as possible, avoid the use of shims between the tie-plates and ties. They wear out quickly reducing the holding ability of spikes which could affect the track gauge and surfaces. Thin and superfluous shims between cap and piles should also be avoided because they work loose and decay under traffic, thus affecting the integrity of the bridge components.

Where plate-cutting of ties exists, the tie-plates should be replaced with those having larger bearing areas. Ballast used on bridge decks should consist of firm, good quality free draining material. Fouled ballast retains moisture which accelerates decay of deck. The amount of ballast should be sufficient to allow adequate dispersion of the axle loads and yet not much to add unnecessary dead load to the bridge. Excess amount of ballast adds dead weight and causes reduction in the live load capacity of the bridge. So, at some point it becomes necessary to raise the deck and remove the excess ballast. Where the ballast depth is such as to require more than one tier of curb timber, the additional tiers should be properly designed to support the retained ballast. On open decks of bridges, the use of rail anchors is not considered desirable because the movement of rails due to temperature changes could cause skewing, bunching or mechanical damage to bridge ties.

2. EARLY REMEDIAL MAINTENANCE:

Decay or damage is present but not to the extent that would necessitate restrictions to regular traffic on trestle. Maintenance activities are intended to rectify the situation and to prevent further deterioration. Maintenance actions may include:

(a) Preservation from Further Deterioration such as in-place treatment of bridge components with preservative chemicals to prevent or arrest decay. In-place treatment provides an effective and economical method for extending the service life of timber bridges. Generally some decay should be present before such treatment is cost effective. Two types of treatments applied are: i) Surface treatments to prevent infection of exposed wood and ii) Fumigants to treat internal decay.

i) Surface Treatment: These are applied to the existing bridge members to protect exposed, untreated wood, or to supplement the initial treatment some years after the installation. Preservatives such as creosote heated to 65°C or more, penta or copper naphthenate is applied by brushing, squirting or spray flooding the wood surface. In addition to liquids, greases or pastes, generally using sodium fluoride, creosote, or pentachlorophenol are applied with brush or trowel on vertical surfaces or openings of piles, posts etc. from several centimetres above the groundline to 40 to 60cm below the groundline and then wrapped with polyethylene.

ii) Fumigants: In liquid or solid form are placed in pre-bored holes to arrest internal decay. Over period of time, the fumigants volatize into toxic gases that move through the wood, eliminating decay organisms. Fumigants can diffuse in the direction of wood grains for 200cm or more in vertical members such as piles and for 50 to 100cm from the point of application in horizontal members such as caps. The three chemicals most commonly used are: Vapam (33% sodium N-methylthiordicarbamatel), Vorlex (20% methylisothiocyanate, 80% chlorinated C3 hydrocarbons), and Chloropicrin (trichloro nitromethane). For fumigant treatment to be effective, application
should be made to sound wood. Fumigant treatment eventually diffuse out of wood. A ten year cycle of treatment is recommended.

The preservatives and fumigants used for in-place treatment are very toxic substances. Their use in the proximity of streams and other sources of water on which fish or other life depends must be made in accordance with the health and environmental regulations. Further, metal tags should be installed on members to warn people of the date and the type of treatment applied.

b) Substitution of Deteriorated Members or portions thereof such as spot renewal of ties, changing of stringers, caps and sills and adding extra piles etc.

c) Compensating the Deteriorated Members for loss of strength by mechanical repairs or by addition of new material or new components such as installing helper stringers, piles or bents etc.

Mechanical Repairs may consist of Member Augmentation, Clamping and Stitching, Epoxy Repair and Pile Rehabilitation.

i) Member Augmentation: Involves the addition of material to reinforce or strengthen the existing member by increasing its section and thus its load capacity with wood, concrete or steel plates. This involves the addition of splice pieces that are lapped over the split or deteriorated members or joined together using epoxy as an adhesive. Steel sleeve may be placed around piles and filled with concrete.

ii) Clamping and Stitching: Is used for splits which could develop from overloads or poor design details that introduce tension perpendicular to grains at connections. Typical examples are the vertical splitting of piles and horizontal splitting of caps. Cracks, splits, or delaminations in timber members can be arrested by stitching with bolts and clamping with steel assemblies.

iii) Epoxy Repairs: Epoxies consist of basic resins and resin hardening agents that are blended together in a gel form. An epoxy is used for timber as a bonding agent (adhesive) for posting piles or as a grout (filler) for filling checks, splits, insect damage and decay voids. The epoxy seals the affected areas, preventing water and other debris from entering, restores bonds between separated sections, increases shear capacity and reduces further splitting.

iv) Pile Rehabilitation: The two methods are employed (see Figure: 6) for piles loaded are: Pile Posting or Restoration. Pile posting where the section is completely removed and a new section is installed with a gap of 3 to 6cm. Holes are drilled at steep downward angle above each joint spaced approximately 90° apart. Steel pins are driven for mechanically joining of sections and then sealed along joints with epoxy gel, plastic film or tape and epoxy is injected under pressure to fill the joints. Pile Restoration on the other hand involves the removal and the replacement of a vertical wedge shaped section of pile rather than the entire section. A metal band is installed to hold while the replacement epoxy cures. This method is more expensive than posting.

3. Major Maintenance:

At this stage the deterioration has progressed in the main load carrying members from moderate to severe, causing loss of strength and making repairs mandatory. This category requires speed and/or weight restrictions for regular traffic. Despite this condition, the cost of the repairs involved does not justify the replacement and after the necessary repairs the bridge will have a reasonable service life. This type of maintenance would consist of the renewal of caps, posting several piles, raising or converting deck, partial replacement of deck, addition of piles to existing bents and partial rebuilds.

Economically reparable damage resulting from derailment, collision, winds, fire, ice, flooding and structural failure may also fall in this category.

When an increase of the loading is anticipated, the bridge capacity must be evaluated and necessary upgrading be carried out.

REPLACEMENT

EXTENDING THE SERVICE LIFE OF TIMBER RAILWAY BRIDGES
When deterioration has advanced to a point where repairs would not be cost effective or would not eliminate the existing deficiency or abnormality, then replacement in its entirety or in part of a bridge may be the only answer for continued safe operation. Examples of this situation would be the badly decayed main components, excessive sway, jack-knifing, excessive deformation or movement of components under traffic; irreparable damage from causes discussed earlier; lack of lateral stability owing to insufficient pile penetration or severe frost-jacking of piles and other similar conditions which are endangering the overall integrity of trestle by not being able to provide a safe and reliable train riding surface. A replacement structure should be designed with the best compromise of cost and quality, while minimizing the effects of the agents of deterioration on the bridge as well as the harmful effects of the bridge on the environment.

SUMMARY

A railway timber bridge offers one of the lowest cost per life year of service and yet its apparently diminishing popularity is difficult to understand in today's money-conscious society. This situation demands more awareness of some of the unique properties of timber as a structural material. Adequately designed and well constructed bridges with treated timber have given many years of useful service. With timely and proper maintenance developed on the basis of an effective system of inspections and careful evaluations, the useful service life can be extended for many more years.

REFERENCES

EXTENDING THE SERVICE LIFE OF TIMBER RAILWAY BRIDGES

Figure 1  A timber railway bridge in a natural setting.

Figure 2  Wood damaged by fungal attack.
Figure 3. A timber bridge in Manitoba, Canada, destroyed by a storm in 1915.

Figure 4. Different stages in decay development - incipient, intermediate and advanced.

EXTENDING THE SERVICE LIFE OF TIMBER RAILWAY BRIDGES
Figure 5  Decayed wood - location and outline

Figure 6  Pile rehabilitation

(a) Pile posting
(b) Pile restoration

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