PROLONGING THE USEFUL LIFE
OF RAILROAD TIMBER BRIDGES

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ABSTRACT

In times of downturn in economy, hard competition, high costs, scarce capital and growing consciousness of the necessity to make better use of investment, an increasing emphasis is being placed on maintenance practices which will prolong the useful life of existing railroad bridges.

This paper outlines the various factors which play a role in the deterioration of timber bridges and the maintenance required to effectively prolong the useful life of such bridges. Methods of evaluation of the residual capacity and maintenance, categorized into preventive, early remedial, and major are discussed.

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

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INTRODUCTION

The current downturn of economy and the competition brought about by the deregulatory moves, the high costs of borrowing, the vast outlay required for replacements, and the growing consciousness of the need to maximize yield on investment are only a few of the reasons which have in recent days placed an increased emphasis on finding ways and means to prolong the service life of existing bridges.

Timber railroad bridges (Figure 1) are easier and cheaper to build and maintain than any other kind of bridge. In the seventies, it was reported that there were 2,300 track miles of timber railroad bridges in service in the United States and Canada (Williams and Norton 1976). This not only amounts to approximately 2.5 million MBFM of timber and 5.0 million feet of piling, but also at today's prices represents an investment of roughly 15 billion dollars.

Although their number has dropped since then, due to their replacement with other types of bridge as well as line abandonments, they still represent a significant portion of the railroad bridge inventory. In North America, timber bridges, or trestles as they are often called, have been used extensively as permanent installations on mainline territories, subject to high speeds and heavy traffic. However, they

Figure 1. Typical view of open and ballast deck bridges.
are the preponderant type on branch lines and temporary crossings and frequently as emergency expedients in cases of washouts or other catastrophes.

The introduction and progressive improvement of preservatives and waterproofing treatments have materially extended the service life of such structures. Consequently, a properly designed bridge constructed of well-seasoned and pressure-treated timber is durable and provides a suitable long-life structure of low annual cost per years of service. Not the least important element to be considered here is the proper and timely maintenance, which would further prolong service life for many years.

The advantages and disadvantages of timber bridges could be briefly summarized as follows:

Advantages

1. Low first cost: A timber bridge is far cheaper than any other type - even when built strong enough for today's loadings (Magee 1967).

2. Availability of material: Suitable types and sizes of materials are available at competitive prices.

3. Ease and speed of construction: This is of particular advantage in emergency situations when traffic must be restored.

4. Ease of maintenance: No prefabrication of timber is required, and components can be made at site to suit.

5. Long service life for investment: Depending on the climate and other factors, the average service life of timber bridges using untreated timber is about 25 years, and for treated timber about 55 years. With timely and proper maintenance, this life can be extended considerably.

6. Adaptability to short-term overloads.

7. Resistance to corrosive environments (in steam or in air) compared to steel and concrete structures.

Disadvantages

1. Due to short spans, there is a tendency to collect debris and obstruct the waterway, sometimes causing washout.

2. Danger of fire. However, proper preventive measures could reduce the danger of damage from fire.
The timber used for railroad bridges should be of a firm close texture, which will afford structural members a maximum resistance to decay (Lisko 1967). Also, it should be free from knots, pitch pockets and other imperfections which might impair its strength and durability.

OBJECTIVE

The main objective of this paper is to describe the various factors which could lead to the deterioration of railway timber bridges and the maintenance required to prolong effectively the useful life of the bridge. The paper proposes a methodology for evaluation of the residual capacity of such bridges subjected to different degrees of deterioration. For the reader's convenience, a brief outline of the construction details, fundamental properties and preservation of wood, as applicable to this subject, are also presented.

CONSTRUCTION DETAILS

A trestle is a bridge consisting of relatively short spans supported by bents. The bents may be composed of timber piles and caps properly braced or of framed bents composed of timber posts, caps and sills, braced and supported on mud blocking, on concrete footings or on timber piles, as shown in Figure 2. A bent may consist of 5, 6, or 7 round piles, or square posts transversely secured at the top. The number of piles or posts depends upon the span length, the character of foundation, and the height of bent which affects the lateral stability. When piles are used in bents, the structure is known as a "pile trestle" and in other cases, the bottom and top of the posts are secured by transverse framing under which condition the trestle is known as a "framed trestle". The lateral stability of each bent is obtained by means of sway bracing (planks extending diagonally across the bent).

Because of the scarcity of longer piles, the maximum height of pile bents is often limited to 30 feet. Therefore, for higher trestles, the piles are cut off about ground line and the sill of the bottom panel framed upon the top. In other cases, the bottom of the lower panel bears upon "mud sills" that are 12" x 12" stout sections of timber which rest upon the ground and are of sufficient area to provide the required bearing.

The top transverse members or "caps" are made up of pieces of treated wood bolted together or of prestressed concrete. For multiple storey trestle bents, each storey rests upon a transverse member, sometimes known as an intermediate cap.

The structural members running parallel to the track and spanning the openings between the bents are known as "stringers". They are
Figure 2. Construction detail of timber bridges.
ordinarily cut to a cross-section of 8" x 16", 10" x 18" or 10" x 20". Where larger timber is available, stringers of up to 18" x 28" have been used to span large openings such as road crossings.

Timber trestles are often classified according to their type of deck, namely a ballast deck or an open deck. In the ballast deck, the stringer system is floored with 4" thick planks with 1/8" clear spaces between them. The rails are fastened to track ties and the ballast section, giving a depth of 8" to 9" between the bottom of the ties and the top of the deck planks.

In the open deck, bridge ties (usually 8" x 8" by 10' to 12' long and at 12" centers) are placed over and alternatively fastened to the stringers using 3/4" diameter lining spikes, and 4" x 8" timbers or flat steel bars are nailed near the ends of individual ties to maintain their spacing.

**PROPERTIES OF TIMBER**

Timber is cut and machined from trees, which are products of nature. Approximately 30,000 different species of trees exist, so it is not surprising that timber is an extremely variable material.

1. **Moisture Content.** Timber is hygroscopic; that is, it absorbs moisture from the atmosphere if it is dry and correspondingly yields moisture to the atmosphere when wet. The moisture content of large timber is rarely uniform. Green wood (newly felled) which is high in moisture content undergoes dimensional changes with alterations in moisture content and temperature. The significance of such changes in dimension is much greater in the case of moisture content than those resulting from temperature.

   In order to avoid shrinkage of timber after fabrication, it is essential that it be dried to a moisture content which is in equilibrium with relative humidity of the atmosphere in which the fabricated piece is to be located. Moisture in timber has a pronounced effect not only on its strength, but also on its stiffness, toughness and fracture morphology. Modulus of elasticity and strength increase with decrease in moisture content below fiber saturation point.

2. **Temperature Effect.** Temperature affects the size of wood, its moisture content at any given relative humidity, and its thermal conductivity. It maintains strength with increasing temperature and time of exposure. At low temperatures accompanied by high moisture content, the strength of wood increases with increase in moisture.

3. **Mechanical Properties.** Numerous factors influence the strength properties of wood, the main ones being anisotropy and slope of grains; defects such as knots, knot holes, splits, checks, shakes; ring width;
ratio of late wood to early wood; cellular structure; moisture content; temperature and rate and duration of loading.

The values of allowable stresses in bending, compression, and shear as well as the modulus of elasticity for different species and grades of structural timber are given in detail in the American Railroad Engineering Association Manual (1986) and Wangaard (1979).

The stress-strain relationship for wood is complex, for the following reasons:
(a) timber does not behave in a truly elastic mode, but its behaviour is rather "time-dependent", and
(b) the magnitude of strains is influenced by a wide range of factors such as density, slope of grains relative to direction of load, cell wall characteristics, temperature and humidity.

When a sample of timber is loaded in tension, compression or bending, the deformation obtained is proportional to the value of applied load only at the lower levels of loading. However, the behaviour becomes nonlinear above the proportion limit.

TIMBER BRIDGE DETERIORATION

The factors which may cause damage and gradual deterioration of railroad timber bridges could be summarized as follows:

1. **Traffic.** The dynamic effect of trains in general sets up vibrations which in time have adverse effects. Of particular mention in this respect are the "unit" trains, i.e., trains made up of cars of the same type and loading, and certain combinations of "car types and speeds" which would set up resonance and cause a marked increase in the displacement, shifting of components or jack-knifing of multiple storey bents.

   Although timber can take a fair amount of instantaneous overload, sustained loads could cause creep in wood, the consequence of which may be the loss of capacity.

   Derailment, or dragging equipment may damage the decks of bridges, and vehicular or boat collision may cause damage to the underside of stringers and bents of a bridges. Use of appropriate guard rails, protective curbs and navigation guides can minimize such damage.

2. **Weather.** Temperature variations affect moisture content and cause wood to check and split due to shrinkage. Wetting and drying cycles tend to leach out the treatment and the extractives in wood which provide natural resistance to decay. Proper seasoning and protection from direct exposure to sun would help to minimize these effects.

   Sub-zero temperatures cause frost jacking of piles, particularly where there is insufficient penetration below the frost line. Differen-
tial heave of piles make it difficult to maintain track line and surface.

Strong winds affect the lateral stability of bridges. The old timber bridge at Uno, Manitoba as shown in Figure 3, was completely demolished by a gust in 1915.

Regions of heavy rainfall and warm temperatures present more ideal environments for the initiation and rapid growth of decay than regions with frigid and arid climates. Therefore, bridges situated in areas having low rainfalls (i.e., less than 25 inches per year) or short growing seasons will have a reduced potential for decay.

3. **Environment.** As a combustible material, timber is susceptible to damage or loss by fire. Fire may start from the deck by dropped burning fuses, from brake shoe slag, or may result from a grass or forest fire (Figure 4). It may have been set off accidentally by a collision, a derailment lightning, or it may be the result of some practice or an act of vandalism.

4. **Stream.** Damage resulting from flow may include erosion of banks, scour, undermining of foundation, and washouts. Drift in flow or material from broken beaver dams, ice movement or build-up could block the bridge on its upstream side and cause considerable damage unless adequate protection is provided. A typical case relating to stream damage, depicting driftwood piled against the bridge is shown in Figure 5.

5. **Soil Conditions.** Shifting ground, unstable embankments and earth slides may cause movement of components. The bents where piles have been driven through weak strata may lack in lateral stability and sway under traffic. Piles subject to overloads, or those driven inadequately and therefore not developing the required resistance, may settle differentially or pump (move vertically), affecting line and surface of track on the bridge (Figure 6).

6. **Work Practice.** Work practices, although carried out for very good reasons, may indirectly have detrimental effects on timber bridges.

   (a) To accommodate grade raises, ballast has to be added to the deck or the deck has to be lifted by means of shim blocks. Ballast depth exceeding the amount used for design would reduce the deck capacity and also require properly designed curbs. Raising decks by addition of more than one cap block weakens the bridge longitudinally.

   (b) Frequent spiking during rail re-lays renders the ties spike killed. Edging ties reduces protective treatment, thus enhancing the opportunity for early decay. Use of rail anchorage systems which do not require removal of wood fasteners during rail removal would eliminate this problem.
Figure 3. Failure of bridge at Uno due to gust, 1915.

Figure 4. Complete loss of timber bridge by fire, Windy Point, Ontario
Figure 5. Driftwood piled against a bridge.

Figure 6. Vertical movement (pumping) of pile.
(c) Bridge spans are substantially stiffer than track sections, and approaches are required at the ends to provide a smooth transition. Therefore, if there is insufficient ballast behind the dumpwalls, the intended objective is not met and the outcome is that the end portions of the bridge would be subjected to higher impacting forces.

7. **Insect attack on wood.** Insect attack can take one of two forms. First, timber is consumed by insects such as "termites". Few timbers are immune to attack by these voracious eaters, but, fortunately, these insects cannot survive the cooler weather. The second form of attack is tunnelling in wood for hatching eggs and nesting by such insects as beetles and ants. The beetle lays its eggs on the surface of the timber, frequently in surface cracks or in cut ends of cells, and these eggs hatch to produce grubs which tunnel their way into the timber. Considerable destruction to wood is done by termites, beetles and carpenter ants.

8. **Marine borers.** Timber used in salt water is subject to attack by marine boring animals such as the shipworm (teredo) and the gribble or wood louse (lemoria). They are particularly active in warm waters. The degree of hazard varies with the salinity and other local conditions.

The insect attack can be prevented by impregnation with toxic chemicals.

9. **Wood decay.** The main factor which causes deterioration in a timber bridge is undoubtedly the decay of wood. Decay or rot in wood is caused by simple living plants called "fungi", which have the unique capability of breaking down and utilizing wood cell wall material as food.

As the fungi attack, the wood cell walls may be perforated or thinned, or the walls of adjacent wood cells are disassociated and consequently the structural strength of the wood is lost. At the same time, the porosity of the infected wood increases. The greater porosity results in more water absorption during a given interval of rain or other wetting, thus increasing the rate of decay. At the same time, an increasing number of growing mycelia occupy a margin of expanding infection and this accelerates the rate of decay. Because of the foregoing reasons, once decay has started, it continues to grow at an exponential rate. At an early stage, the incipient decay is detected by discoloration of wood which otherwise appears to be firm and solid. This is quite often followed by "medium" or "advanced" decay, which is noticeable by decided softening and breaking down of wood.

All of the following four conditions must exist to support decay fungus growth, hence, depriving the fungi of these conditions will effectively curtail decay in wood.

(a) Supply of oxygen. Although a very small amount of oxygen is necessary for dormant existence, some free oxygen is needed for decay
fungi to survive and grow. Unfortunately, this condition cannot be utilized for controlling decay, except for piling which is submerged in water or buried in the ground at a point below the oxygen line, usually 4 to 10 feet.

(b) Favourable temperature range. At temperatures of 32°F or less, fungi become dormant but are capable of resumption of growth as the temperature rises above freezing. Between temperatures of 32° and 90°F, the growth rate of fungi gradually increases from near freezing to an optimum range at approximately 75° to 85°F. At temperatures greater than 90°F, the growth drops rapidly. Only temperatures in excess of 100°F are lethal for most decay fungi.

(c) Adequate supply of food. The supply of food in cell walls is generally available in abundance. Although most woods possess a certain degree of natural resistance to decay, the sapwood is often less resistant than the heartwood, and thus is an adequate food source when other conditions are favourable.

Decay can be prevented by poisoning the food supply with toxic chemicals. The wood treated with these chemicals or preservatives must receive a sufficient quantity of the preservatives to effectively kill the wood destroying fungi on contact (i.e., threshold limit) and to prevent new growth of the organism.

(d) Available water. Dry wood will not decay. Moisture content is one of the most important factors regarding wood decay, because a considerable amount of water is required for fungus growth. Therefore, in many instances the moisture content of the wood in service is subject to control.

In bridge structures exposed to natural weather cycles, variations in moisture are likely to be broad. Fungus activity is directly affected by the moisture content of wood in the immediate vicinity of the infection. Thus, a member may be well seasoned and generally dry, but can be infected and severely decayed at localized areas such as (i) water trapping checks, that is in curb timber, bridge ties, stringers and caps; (ii) in the proximity of a joint interface at the ends of the stringers; (iii) at points where the wood is continuously or repeatedly wetted at short intervals, i.e., water surface levels; (iv) where the wood is inhibited after wetting such as bearing areas of ties, stringers, caps and posts and fastener holes; (v) soil contacting members such as piles near ground surface, mud sill and dumpwalls.

The primary source of hazardous wetting is rain, although snowmelt, condensation, and stream or ground water are also important sources.
The degree of penetration by water into wood members depends in part on the wood face exposed to wetting. The end-grain surfaces of wood absorb water much more rapidly than side-grain surfaces, permeability in the longitudinal direction is 50 to 100 times greater, all things being equal, than in the transverse direction.

Preservatives and treatments have a dramatic effect on the control of decay and wood durability. The important feature of any preservative is its toxicity to the already established fungal activities and prevention of any further deterioration. It should also possess good penetrating qualities, be leach resistant, and not adversely affect such properties of wood as swelling, shrinkage, and strength. It should provide a clean appearance, combustion resistance, water resistance, low cost, and be harmless to mammals. No single preservative in use today possess all these qualities.

(a) Preservative treatment of wood: Wood preservatives are broadly divided into two types: oil borne, such as creosote or creosote-petroleum mixtures, and water-borne, such as borax, sodium fluoride and chlorinated phenol compounds.

(b) Treating processes. Various processes are used to protect wood, depending on the degree of hazard and quantity of preservative needed. Light retentions permit nonpressure treatments such as brushing, dipping, spraying or diffusion. Heavy retentions require preservative impregnation under high pressures in enclosed cylinders such as full cell process (Bethel) or empty cell process (Lowry and Rueping) (Burpee 1958).

EVALUATION OF WOOD BRIDGES

The variations in designs, material characteristics, maintenance practices, ages and site environments are only a few of the factors that make detailed recommendations for inspection of trestles somewhat impractical. However, some basic considerations which are common to most cases are included here. Detailed checklists of items to be inspected are discussed in Williams (1976), Eslyn and Clark (1979), American Railroad Engineering Association Manual (1986), and U.S. Department of Transportation Bridge Inspection Training Manual (1971).

The inspection of a wood bridge should be undertaken systematically, that is, working from the lowest level of the substructure to the top of the superstructure or in reverse order. The behaviour under the movement of trains should be observed where practicable to evaluate the overall riding quality and integrity of the timber bridge, and for signs of excessive crushing, splitting or deflection, side sway, vertical movement of piles, jack-knifing or abnormal slackness of joints, presence of forced-out water from interface areas or any other abnormal conditions.
Inspecting for Decay

Attention should be given to visual evidence of conditions conducive to decay developed in specific areas of member parts such as (a) excessive wetting, indicated by water marks or stains (Figure 7), (b) rust stains, when water penetrates fastener holes, (c) plant growth, or any appreciable growth of moss, grass or other vegetation on surfaces or in checks or cracks, (d) water traps and joint interfaces, where water has access to end grain areas.

Attention should also be given to visual indicators of the presence of decay. These are (a) fruiting structures in recessed, partially enclosed or shaded areas of wood (the fruiting structures are mushroom-like, shell or hoof-shaped projections of flat, leathery material), (b) abnormal surface shrinkage or "sunken" faces (Figure 8), and (c) insect activity, such as carpenter ants, beetles, termites and marine borers.

If decay is present in areas which could effectively reduce the load-carrying capacity of the member, such areas must be appraised accurately. Figure 9 is a sketch showing some examples of the locations where decay may occur (Eslyn, 1979). It also emphasizes the association of decay with penetrating fasteners. All of the decay indicated is interior and not likely to be detected without boring or coring the infected areas.

The methods generally employed for detection of decay are as follows:

(a) External decay. The detection is carried out visually or with a sounding device. This could be supplemented by probing with a pointed tool such as an awl or a rock pick type of hammer. This hammer is also useful for sounding wood members.

(b) Internal decay. A number of nondestructive techniques, using Sonics, Radiography and Mechanical Probing devices could be employed. However, the most common one involves sounding followed by extraction and inspection of cores or shavings. Probing may be used singly or in combination with boring. There are other tools available for detection of decay, but none of them are very practical or cost effective in the field.

In taking cores or bore samples, it is advisable to use sharp tools. Dull tools tend to crush or break wood fibers and produce unsatisfactory samples. Areas which remain wet show signs of high moisture content, or give indications of conditions conducive to decay or the presence of decay itself must be identified prior to boring. Where possible, boring must be made parallel to the fastener hole in order not to miss any decay present at variable depths from the wood surface due to penetration of water. Boreholes may become avenues for decay unless properly treated. After extraction of a core or shavings, a wood preservative should be squirited into the hole and then the hole plugged with a preservative-treated wood dowel.
Figure 7. Typical excessive wetting of stringer and cap.

Figure 8. Typical sunken face.
Figure 9. Sketch showing typical location of wood decay.

The presence of some common timber defects and abnormalities must be anticipated and not be confused with decay. For example, the presence of resin pockets, shakes, abnormal grains, and knots materially affect the character of wood samples. Skill in appraising cores and shavings comes with considerable practice.

ASSESSING LOSS OF STRENGTH DUE TO DECAY

There is relatively little information available on strength loss due to amount or severity of decay in bridge members. Therefore, when strength is an important consideration, the safe procedure is to discard areas that contain decay and assume the strength loss to be roughly proportional to the loss of sound wood in the section. Assigning no strength values to any decay results in a desirably conservative estimation of the residual strength in the member. Such estimate is also appropriate because the decay fungi will generally continue and spread until some remedial action is taken. For calculating the residual strength of partially decayed structural members, it is important that the visible portion of the decay infection be outlined, both in its cross-section and its length. In defining the area of decay, allowance must be made for nonvisible, incipient decay that extends outwardly from visibly decayed areas. The areas thus defined could be represented in convenient geometrical configurations (i.e., rectangles, triangles, circles, ellipses, or annular shapes, and combinations thereof) for ease
of analytical computation of residual strengths of bridge components.

Computer programs have been developed by the authors which make use of the wood decay information obtained from test borings in the field to determine the residual strength of bridge decks and bent piling. These programs work out, among other things, the residual capacity in terms of Cooper's E-Loading and compare the same with the value from the "as new" condition.

Despite the fact that such analyses are very good aids in decision making, the programs require considerable information on the decay, which has to be obtained from the field. Therefore this technique should be limited in use only to suspect cases or where the cost of extensive field work is justifiable. In clear-cut cases of a bridge being in good or in bad condition, visual examination with or without some extractive boring and less rigorous appraisal would be sufficient.

**MAINTENANCE**

Maintenance is planned work which when undertaken at the right time and in the right manner, effectively enhances the usefulness by prolonging the service life, of timber bridges for many years. For the sake of simplicity, maintenance activities may be divided into preventive, early remedial, and major categories.

Short term gains, budgetary constraints and other requirements often take preference over the need for proper maintenance and, unfortunately, most bridges are ignored until they require major maintenance or their replacement becomes necessary.

1. **Preventive Maintenance.** The decay has not started as yet, but the conditions conducive to decay or damage are present, and maintenance is required to prevent deterioration. This may include:

(a) Control of moisture. The control of moisture is probably the most economical and practical technique for extending the service life of timber bridges. An example of this is the exceptionally long service life of old covered wooden bridges. Perhaps the most effective method to control moisture on most wooden bridges is to prevent moisture infiltration in wood by application of moisture-proof coatings such as bituminous or asphaltic mastic in addition to or in lieu of sheet metal, roll roofing material at end grain areas such as top of pile and posts (Figure 10), joint fillers and seals as check filling compounds in exposed horizontal components and impervious membranes such as heavy plastic or neoprene between deck and stringers to prevent damage to stringers. Similarly, prevention of moisture entering into wood through areas which have suffered from loss of treatment by mechanical damage, cutting, dapping, holes, and edging operation may be achieved by mopping or squirting the treatment over affected areas.
(b) Control of fire. Keeping the timber bridge and its immediate proximity clear of grass, brush or other combustible material, keeping the bridge timber clean and free from frayed fibers, taking extra care while using a flame torch, performing rail slotting, rail welding or other activities involving flame or spark about a timber bridge are only some of the measures which help prevent fires at the site.

Other preventive measures could be the provision of water barrels, fire breaks, firewalls, ballast decks, or use of fire retardant chemicals. Generally, two methods are used for applying the fire retardant chemicals: (i) Painting of surfaces with protective material so as to reduce ignition from sparks. The coating materials used include sodium silicate, Non-Flam, a proprietary name for a ceramic based mixture in volatile fluid, or different forms of high boiling asphalt paints. These coatings have been found to be effective to varying degrees, but as yet, none has given full protection. (ii) Impregnating wood with a chemical which will liberate noncombustible gases when heated. Various ammonia salts have proven effective. The main disadvantage of these salts is that, being water-based, they leach out in time.

(c) Periodic cleaning of stream. Having relatively short span lengths, timber bridges tend to trap the floating matter in the flow, or when a beaver dam collapses, its material gets accumulated on the upstream of bents. Thus, if periodic cleaning is not undertaken, ponding could result, which may damage the bridge or erode the banks. Stumps of old piles also present obstructions to navigation and flow. Infected old pile stumps can transport fungi to good wood, causing early
decay. Therefore, all old pile stumps should be cut down to stream bed level or below the ground level and covered with earth. Where conditions warrant, adequate erosion protection and ice protection should be provided.

(d) Control of vibrations or component overloads. Timber bridge deck components should be designed so as to make their connections flexible enough to permit necessary deformations under live loads. Ties, stringers, caps and piles should possess uniform bearing at their support points and neoprene or other cushioning pads may be employed to account for minor misfits. When bridge timber has twisted due to shrinkage or where piles have sunk or frost jacked causing loss of bearing, they should be immediately shimmed to avoid overload on adjacent members. Fasteners need to be retightened a couple of years after the construction of a timber bridge and at periodic intervals thereafter to ensure adequate functioning of the components. Dumpwalls are also often raised to suit track lifts. Since they are designed to retain a given depth of backfill, they must be reinforced for any added heights.

(e) Other practices. Always keep the bridge site clean. A tidy bridge is usually free from common hazards. A bridge approach having poor crib or lacking in fill causes high impact to the bridge extremities, necessitating added maintenance. Provide full ballast section at the bridge approaches. Dumpwalls are not normally designed to take the direct train load, but just to retain the backfill. To prevent this, the tie plates should not rest on the dumpwall, but instead, a gap should be provided between the rails and the dump to avoid rail contact.

As far as possible, avoid placing shims between tie plates and ties. They wear out quickly, reducing the holding capability of spikes, thereby affecting the track gauge, surface and line. Thin and superfluous shims at locations such as between cap and piles should be avoided as well, because they work under traffic getting loose and rotten, and affecting the integrity of other bridge components.

Ballast used on ballast decks should consist of firm, good-quality free draining material. A poorly draining ballast would accelerate rot in the deck. The depth of ballast should be sufficient to ensure good riding quality for trains. Where ballast depth is such as to require more than one tier of curb timber, the additional tiers should be designed adequately. An excess amount of ballast adds more dead weight and causes a 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.

On open deck bridges, continuous welded rails should not have rail-anchors because any movement in rails due to temperature variations can cause skewing, bunching or other damage to bridge ties.

2. Early Remedial Maintenance. Decay or damage is present, but not to the extent where restrictions are required for normal traffic on the bridge. Maintenance is needed to rectify the situation and/or to
prevent further deterioration. The rectification may involve (a) substitu-
tion of deteriorated members or portions thereof such as spot
renewal of ties, posting of a pile or changing the odd brace; (b) com-
penating for the loss of strength by addition of new material to the
existing members, such as helper stringers, piles, posts or bracing, or
(c) reinforcement with totally new components, such as collar or crow-
foot bracing, additional bent supports where movement in the longitu-
dinal direction is a problem, ice breakers, navigation guides and thrust
braces and posts where stream is a problem.

Preservation from further decay generally involves in-place
treatment of bridge components. The preservatives are applied by brush,
flooding or diffusion. Both oil-borne and water-borne preservatives
have been employed for the supplementary (in-place) treatment of bridge
components. For this treatment to be cost effective, some decay should
be present in the wood.

One of the commonly used treatments of timber piles is at ground
line. For this, the soil is dug to a depth of 1-2 feet around the base
of the pile, and obvious rot and dirt on the surface of the butt are
removed. Gelled preservatives are then applied by brush or trowel. The
active ingredients of the treatment emulsion gradually diffuse into the
wet wood. Heavy, water-resistant paper is wrapped around the treated
area, and the soil is replaced.

In lieu of posting of reject piles, in-place restoration with
epoxy and cement grouts has also been attempted by some railroads with a
certain degree of success (Brookings 1983). The procedure involves
windowing the decayed pile section, removing the decayed wood and
filling the space created with grouts under pressure.

3. Major Maintenance. The deterioration has progressed in main
load-carrying members from moderate to severe, causing loss of strength
and making repairs mandatory and/or requiring speed and weight restric-
tions for normal traffic. Despite the condition, the cost of the
repairs involved does not justify the replacement and after the neces-
sary repairs, the structure would still have a reasonable remaining
service life.

Examples of this type of maintenance include cap renewals, posting
several piles, change-out of mud sills, raising and shimming decks, deck
replacements, addition of piles to existing bents, and partial rebuilds.

Economically reparable damage caused by derailment, collision,
wind, fire, ice, flooding and structural failure also falls in this
category.

4. Replacement. When deterioration has advanced to a stage where
repairs will not be cost effective or will not eliminate existing
weakness or abnormality, then replacement of the bridge is the only
answer for continued safe operation.
Examples of this condition would include badly decayed major components, excessive sway, jack-knifing, deflection or excessive movements in members under traffic, irreparable damage resulting from causes discussed earlier, and lack of stability owing to insufficient pile penetration or severe frost jacking of piles, endangering the overall integrity of the structure by not providing a safe and reliable train riding surface.

SUMMARY

Despite the fact that a treated timber bridge offers one of the lowest costs per life year of service, including the cost of its damage or loss by fire and the consequent disruption of traffic as compared to those in steel or concrete, its diminishing role is difficult to comprehend and demands more awareness in today's money-conscious climate.

Properly seasoned and well treated material, and appropriately designed details which provide effective control of moisture, fire and other hazard are very important. An important factor in assuring long and useful lives for railroad timber bridges is an effective inspection and evaluation system followed by a timely and adequate preventive and remedial maintenance program. As a treated timber railroad bridge deteriorates, meaningful maintenance procedures (including supplementary treatment and field restoration) will significantly prolong its useful service for many years.

REFERENCES


