



# STOP THE ROT

## Stabilisation of Historic Timber Structures

Owen Wilkes and David Page

INTERIM GUIDELINES



Department of Conservation  
*Te Papa Atawhai*

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# 1. INTRODUCTION

This manual describes operations that may need to be undertaken to prevent or slow down deterioration of old timbers in historic structures exposed to the weather.

The steps are described in a particular sequence which in most cases would be the ideal sequence. Practical considerations will often intrude, however, and it may be necessary to vary the sequence.

This manual takes a perfectionist approach to structural stabilisation. It will never be possible, and in some cases may not be necessary, to undertake every procedure recommended here. Hard decisions may have to be made, and the project manager must decide what is feasible and what isn't. Some heritage values may have to be sacrificed. The manual tries to define which operations are mandatory and which can be deferred or omitted, and lists many of the criteria for deciding these matters.

The guidelines are interim in the sense that better techniques and more appropriate chemicals may come to light in future years, in particular as more information is collected from the ongoing preservative trialing projects described below.

We are reasonably confident that the procedures described here do work and do not have significant adverse effects. However no stabilisation treatment lasts forever. Suggestions are made as to when re-treatment of any treated structure will probably be necessary. Use of the procedures and materials described here will not prejudice switching to better treatments and materials for future re-treatments.

The Department of Conservation (DOC) has already treated a number of structures using a variety of procedures and chemicals. Current research suggests that some of these treatments, especially those using low concentrations of TCMTB (i.e., Busan) have not been effective and should be replaced by the treatments recommended here. Other treatments are working quite well, and when re-treatment of these structures becomes necessary the original treatment may be repeated, if for no other reason than to expand our knowledge of the relative advantages of the different treatments.

This manual assumes that all the processes involved in stabilising a particular project will be treated administratively as a discrete project. Each such project will have a project manager, who will usually be a conservancy historic resources technical support officer.

The project was managed and funded by the Science and Technology Centre, Department of Conservation, Wellington.

## 1.1 EXPERIMENTAL AND DOCUMENTARY BACKGROUND

This manual is based on a wide variety of information sources including:

A set of trial treatments using various chemicals on an old Howe truss railway bridge built from durable eucalypt at Waikino, near Waihi. The trial panels were treated in 1999 and are being monitored at one year intervals by Dave Page in a project led by Mick Hedley of Forest Research on behalf of DOC.

A similar but scientifically less rigorous set of trials established by Owen Wilkes on a kauri driving dam in the Kauaeranga valley. Small scale trials are also underway on a variety of timbers including totara at Kawhia.

Personal involvement by Owen Wilkes in timber stabilisation on two other kauri driving dams in the Kauaeranga valley.

Inspection of a wide variety of other historic wooden structures on which DOChas attempted timber stabilisation, including truss bridges, suspension bridges, tramway sleepers, and slab huts. In some cases samples have been taken from these structures and assayed to determine the retention of preservative chemicals by the timber surfaces. The assistance and hospitality of DOChistoric resource staff is gratefully acknowledged.

Published information, including material from the New Zealand Forest Service and the New Zealand Timber Preservation Authority, and articles in overseas technical journals. The National Forestry Library at Forest Research, Rotorua, has been particularly useful as has Australian and Scandinavian research. Information about various chemicals has been supplied by manufacturers.

Consultation with various timber preservation practitioners, in particular Jack Fry of Conservation Supplies, Wellington.

An enormous amount of information and experience accumulated and readily shared by Forest Research, Rotorua, and conversation with Mick Hedley and Robin Wakeling at Forest Research. "Graveyard" trials of various preservatives at Rotorua yielded important insights.

Jack Fry has sold  
Conservation Supplies. Jack  
still lives in Wellington.  
Conservation Supplies is now  
in Auckland.

## 1.2 FURTHER INFORMATION

A good general textbook on prevention and treatment of fungal rot (although it is becoming out-of-date) is Wood Preservation by Barry A Richardson, 1978 (Construction Press, Lancaster, UK)

For information on hazards associated with timber preservatives see Approved Code of Practice for the Safe Use of Timber Preservatives and Anti-sapstain Chemicals. Occupational Safety & Health, Department of Labour, 1993.

There is a reference associated with commercial preservative disposal, probably only relevant to boron from the Ministry for the Environment, i.e., Health and Environmental Guidelines for Selected Timber Treatment Chemicals, ME240, 1997.



### 1.3 Scope

This manual is intended to provide guidance for stabilising historic timber structures in which the timbers of concern are exposed to the elements, rather than protected by roofs or by paintwork.

The structures of most concern are bridges, and most of these bridges will be made of durable eucalypt (often referred to as “Australian hardwoods”, - jarrah, ironbark etc.). Other types of structures and other timbers are mentioned in passing, and are dealt with more fully in appendices.

Totally waterlogged timbers such as those in submerged shipwrecks or Maori carvings recovered from swamps are outside the scope of this manual.

Following field tests a supplementary bulletin should advise on treatments for weatherboards, slabs, shingles, new poles and wood in concrete.

A follow-on research project should review treatments that provide protection against weathering which is particularly prevalent on north facing and horizontal faces. Some projects have applied a micocrystalline wax with a UV (ultra violet) filter.

### 1.4 THE NATURE OF TIMBER DECAY

Fungal rotting is the main cause of decay in timber, but other influences are also at work. Decay in typical New Zealand situations is caused roughly as follows:

- 65% Fungal rot - mostly caused by brown rot and white rot fungi. Soft rot is important on damper timber, and may be responsible for as much as one fifth of fungal rot.
- 25% Weathering - less important than fungi in New Zealand but may be important in structures that are relatively dry and contain sapwood. The preservatives recommended here are effective against fungi and insects.
- 7% Insects - generally not important in New Zealand, and the fungicides recommended here usually discourage insects.
- 5% Bacterial rot - operates very slowly, but may be dominant in very wet timber. Ignored in these guidelines.
- 3% Chemical rot - particularly around iron fasteners embedded in the wood, so can be locally important.

### 1.5 CHOICE OF PRESERVATIVE

Preservative formulations are all based on fungicides, but a good fungicide does not necessarily make a good preservative. There are many factors to be considered when choosing a preservative, including:

Fungicidal effectiveness - some fungicides are effective against a broad spectrum of fungi, others are more specific.

Water repellency - to slow down the entry of water into wood, while allowing free exit of water vapour.

Retention - the ability to lodge in or on the wood in sufficient amount to control rot.

Penetration - the ability to soak in as far as is needed to control rot.

Permanence - the ability to resist leaching out by water, degradation by ultraviolet, detoxification by micro-organisms etc.

Environmental impact, both during application and afterwards.

Worker safety, during application.

Visitor safety, subsequent to application.

Ease of application.

Historical appropriateness, aesthetic issues etc.

Cost.

No single preservative will excel in all these considerations, and different preservatives are needed in different situations. In particular, the control of surface rot requires a preservative which will fix permanently in the wood near the surface, while control of internal rot requires a preservative which will diffuse into areas where decay is active.

The requirements for remedial treatment are quite different from those for preventative treatment of, e.g., radiata pine used in building, and the copper-chrome-arsenic (CCA) preservatives used in pressure impregnation of radiata are not suitable. Most requirements for remedial treatment of historical structures can be met by four preservatives - copper naphthenate, creosote, boron, and "Busan" pole preservative gel. The interrelationships between these four are shown in fig. 1, and the detailed reasons for choosing them are listed in Appendix 1 which also contains details of various remedial treatment preservatives.

Some preservatives have not been recommended because they are likely to be less effective, e.g., Busan 30WB. DOC-sponsored research indicates that if this preservative is to be effective on historic structures, then it needs to be applied at ten times the concentration used in the past, and the treatment needs to be repeated every two or three years if it is to remain effective.

It is often asked why we can't use CCA (or "tanalising") treatments on historic structures, since it is so obviously successful for fence posts etc. The short answer is that CCA preservatives chemically bind to wood and will not diffuse through wood so will only penetrate wood when forced in under high pressure. There are also serious health hazards in any hand-application of chromate and arsenate salts.

### **1.5.1 Copper naphthenate**

Copper naphthenate performance was variable. This variability was associated with the substitution of naphthenic acid by other acids in the formulation. Recent formulations have been more consistent.

CN (copper naphthenate) is well established in New Zealand for remedial use, having been manufactured here since before World War II. There is lots of documentation on both its virtues and its faults. Contractors are familiar with it and comfortable working with it. It is a general-purpose spray-on brush-on surface preservative. Being oil-based it has some water-repellency. It is nearly

as safe to use as oil-based paint, and it is relatively cheap. It is effective against nearly all the rot fungi we are likely to have to deal with. It is available as an emulsion (CNE) especially suited to brushing-on, and as a liquid (CNL).

If environmental contamination with CN should occur it will have little biological consequence, except for fungi. Even if CNE gets onto soil or into water it is of relatively low toxicity to higher plants, fish, arthropods, birds and mammals.

On the negative side there is at least one variety of rot fungus (*poria* sp.) with the ability to detoxify CN. (But this hasn't been a big problem so far in New Zealand.) CN also loses some potency with time as it hydrolyses, leaving copper alone to provide fungicidal effect. The naphthenic acids used to make CN can vary and thus performance of CN is somewhat unpredictable from batch to batch. The bright green colour of copper naphthenate fades quickly to leave wood surfaces a slightly greenish colour.

### **CNE (copper naphthenate emulsion)**

CNE is formulated specifically for remedial treatment as a “bodied mayonnaise-type” (BMT) emulsion. When it is applied to a surface it demulsifies. The oily component containing the copper naphthenate begins to soak into the wood while the watery component forms a crust at the surface which prevents wash-off by subsequent rain etc. This maximises the possibilities for deep penetration and high retention, even in wood with fairly high moisture content. CNE can be spread on quite thickly (2 mm on side grain, 5-6 mm on end grain) and will slowly soak in over the next few days. The carrier oils remain in the timber for a long time, and have the ability to “creep” into checks (longitudinal fissures developed during weathering) or cuts which open up after treatment.

As a moderately viscous emulsion CNE can be applied easily and cleanly, with little risk of environmental contamination. It does not splash or drip. If a bucket of CNE is kicked over it will not spill. If a bucketful should be accidentally dropped into a waterway it will disperse only very slowly, allowing plenty of time for it to be retrieved. Workers are unlikely to come into contact with it providing impermeable gloves are worn.

CNE is thixotropic, which means that it becomes momentarily more liquid while being brushed on so that it is easy to apply. If it is brushed on across the grain the checks in the timber will fill up with emulsion. Over time the CNE will “creep” further down into the checks.

Timber recently treated with CNE has a rather garish azure green colour, but this disappears after a few days or weeks. As long as this colour is present anything which comes into contact with it will become stained by it, so temporary barriers to access may need to be set up.

### **CNL (copper naphthenate liquid)**

Copper naphthenate is sold as a 4% solution which can be further diluted. It is particularly suited to application by spray, using an ordinary horticultural backpack sprayer. It is widely available as a do-it-yourself preservative for home use. Our trials indicate it should be diluted 1:1 or 1:2 (rather than 1:3 as recommended by manufacturers), and it is better diluted with diesel than with mineral turpentine because the diesel confers additional fungal toxicity and some slight water repellency.

Application of CNL by spray poses some hazards not present with brush application of CNE. Workers risk blowback, so that respirators, protective clothing need to be worn, and goggles may be advisable, depending on wind conditions. Environmental contamination is also more likely, from spray-over, spray-drift, and dripping. CNL does release volatile organic carbon (VOC) into the atmosphere, with long term implications for global warming etc.

CNL can be applied with brush or roller, but there is likely to be lots of dripping. Brushing is not practicable on upside-down horizontal surfaces. If there are large areas to be treated, where spray-over can be avoided, then spraying of CNL is probably a quicker, more convenient and possibly cheaper option than brushing on of CNE.

If CNL is prepared using mineral turpentine rather than diesel as the carrier it is possible to later paint over the preserved wood.

CNL will probably work out to be cheaper than CNE. In general the same retention can be achieved with CNL as with CNE, but the penetration will probably be less particularly if the wood is damp.

### **1.5.2 Creosote**

The alternative surface treatment for historic structures is creosote. It is a very effective preservative, probably better than copper naphthenate. It was formerly manufactured in New Zealand and widely used. Creosote penetrates well, and remains mobile within the timber for decades, so it can flow into checks which open up after treatment. It is effective against a wide range of fungi, including those active at the groundline. It is not water soluble and gives some water repellency.

Creosote is smelly and dirty, and if it gets on skin it stings and burns. The burning is accentuated by exposure to sunlight. These properties are particularly obnoxious with pressure-treated timber, because pressure-impregnated creosote unpredictably “weeps” back to the surface, so that fencers handling posts and linesmen climbing poles used to become contaminated by it. These problems are largely absent with brushed-on and sprayed-on creosote. Creosote treatment increases the flammability of timber for at least a few days after treatment.

In one sense the very obvious obnoxiousness of creosote is its best safety feature. Anyone who uses it will take great care to avoid contact with it. It is not likely to be seriously toxic in the quantities in which it is accidentally encountered.

New Zealand is one of the few countries in which creosote is no longer used, for historical reasons given in the appendices. Creosote is still widely available and used in Australia, the US, Britain, Japan and Scandinavia. In the 1980s Sweden shifted from CCA back to creosote for utility poles, largely on alleged health and safety grounds. Japan has banned CCA on alleged environmental and safety grounds, but still uses creosote for rail sleepers.

Creosote was formerly widely used in New Zealand, for sleepers, utility poles, fencing, piles, stockyards, farm outbuildings, crib-walling etc. Some county councils treated bridges with it. Farmers impregnated their own fenceposts by hot-and-cold soaking. As a do-it-yourself paint-on it was used for fence palings, post and rail fences, weatherboards etc. Creosote disappeared from the New Zealand market about 1998, and if it is to be used now it will need to be imported.

It is suggested here that it be used for surface treatment wherever it is historically appropriate, as in the situations just mentioned, and wherever its obnoxious properties will not impinge too forcefully on visitors.

Creosote is distilled from coal tar and today is produced as a by-product of coke making for iron and steel plants. In the past it has always been used as the liquid produced at the distillery. More recently a thickened emulsion analogous to CNE has become available in Australia.

Liquid creosote for remedial purposes is usually applied either by brushing or by spray. Because of its low viscosity it tends to splash and drip excessively. For application overhead spraying is the only way. Protective clothing, gloves, respirator and goggles may all be needed, and application should not be attempted in poorly ventilated spaces. Any splashes onto skin need to be cleaned off immediately with warm soapy water, especially in hot sunny weather.

In some situations the hot-and-cold-soak method may be appropriate - for example if there are a large number of moderate size, movable components to be treated, such as fence posts or bridge transoms. The timber pieces are put first into a bath of heated creosote for long enough to drive out air and moisture, and then transferred to a bath of cold creosote. As the timber cools a partial vacuum is created and creosote is drawn into the wood. Great care is needed to make sure the hot-bath creosote does not catch fire - indirect heating, e.g., with steam, is best.

Emulsified creosote has become available only recently, and there is no experience with its use in New Zealand, although it is widely used in Australia for the commercial and remedial treatment of wood. It is said to be as effective as run-of-the-distillery creosote, but with 80% of the smell removed. It should be much cleaner and safer to apply, and is probably the formulation of choice. We hope to undertake trials shortly.

### **1.5.3 Boron**

Boron is a very effective fungicide, and because of the smallness of its molecules, it diffuses readily through timber. It will diffuse right into the cell walls rather than remaining in the cell cavities as is the case with copper naphthenate. This means it can kill soft rot fungi which CN doesn't reach. Unlike copper and creosote it penetrates readily into damp timber - indeed it is dependent on there being at least 30% moisture content present before it will diffuse readily. This means it has a tendency to migrate within the timber to where it is most needed - to the dampest wood. If there is no damp wood, the boron remains immobile, and thus is not wasted.

In some respects boron is too mobile. It is likely to diffuse out of the wood as readily as it diffuses in. It is thus suited mainly to internal use, but may give limited protection in exterior situations when it is used in conjunction with a water repellent or paint coating.

There is little experience with remedial use of boron in New Zealand, although boron diffusion has been used for H1 radiata treatment since the 1950s, and New Zealand is a world leader in this technology. Overseas there is burgeoning interest in boron for both commercial treatment of building timbers and in remedial treatments.

Boron is by far the safest preservative available. Boron has very low toxicity for mammals and most other forms of life. It is however very toxic to arthropods, particularly insects, so care should be exercised if there is concern about, for example, rare giant wetas. Boron is essential to most forms of life, and it is everywhere present in low concentrations in soil and water, it is not bio-accumulative. If it is accidentally released into the environment it dilutes and disperses readily.

Boron needs to be inserted into the wood rather than applied to the outside. Holes are drilled into the timber at carefully chosen locations, and these holes are filled with rods of fused boron and/or boron paste. The paste diffuses more rapidly than the rods and may be more suitable for wood that is relatively dry. Rods deliver more active ingredient for the same volume when compared to the paste but they need a relatively high moisture content in the wood to dissolve them.

Boron is also available in foaming form. The foam has the consistency of whipped cream, and can be injected into voids in timber, where it expands to fill the void and subsequently collapses against the walls of the void, so that the boron is transferred to the adjacent timber. Foamed boron has been used extensively overseas as a way of applying preservative to surfaces in inaccessible spaces such as those between the internal and external cladding of house walls, as well as in the bilge spaces of historic ship hulls. Approval to use foam in New Zealand, if required, is now given by ERMA or under hazardous substances legislation. (Details about boron foams. This needs to be checked with Jeanette Drysdale and potential suppliers. Basic questions about concentration, application and availability need to be answered before we can recommend its use.)

Cavities treated with boron foam can later be permanently filled with polyurethane foam. This is a technique used extensively in Hawaii and North America for renovating utility poles that have been hollowed out by termites or woodpeckers.

#### **1.5.4 Pole preservative gel**

Polegel, as it may more conveniently be referred to, combines an organic fungicide, TCMTB, with a penetrant chemical called DMAD, to give a preservative which will penetrate timber to a greater extent than CN or creosote, but which is not as mobile as boron. It is supposed to be as effective in damp wood as in dry, and in wood below 30% moisture content it may be more mobile than boron. Like boron it will penetrate cell walls. It is not very effective against brown rot/white rot, but is very effective against soft rot, and therefore is particularly useful at the groundline of timbers which rest on or are embedded in the soil, where soft rot is particularly active and otherwise difficult to control. A technique for applying preservative in bandages was developed by the CSIRO in Australia and is widely used in New Zealand for remedial treatment of power poles. (Check efficacy of TCMTB against brown and white rots.)

Polegel is provisionally recommended here for bandaging piles, posts and poles at the groundline. It is recommended with some reservations. Polegel was developed to protect against soft rot in poles which had already been treated with CCA against brown rot/white rot. There are more sophisticated formulations under trial overseas for groundline control, and it is likely that one of these will in the

future be found more suitable for remedial historic purposes than Polegel.

Polegel as a thickened gel used in small quantities and isolated by impermeable bandage is unlikely to cause environmental problems. It is not particularly toxic but it does cause a severe skin allergy with some people, with symptoms like severe sunburn.

Polegel is the most problematical of the four recommended preservatives. It is not widely used outside Australasia, and there is little information about it. It is very expensive on a per litre basis, and it is very expensive to test for.

## 1.6 OUTLINE OF OPERATIONS

(The numbers here correspond to the section numbers of the relevant text)

### **3. Initial assessment**

Is the structure important enough to warrant stabilisation?

Is it feasible?

Is it more urgent than other historic structures??

### **4. Cleaning the structure**

Before detailed assessment or stabilisation can begin dirt, moss, lichen, and completely rotted wood needs to be cleaned off. Waterblasting will generally be the best technique.

### **5. Preparation of plans and elevations**

This allows detailed assessment and operational planning to begin. Later on it will facilitate regular maintenance and management.

### **6. Detailed inspection and assessment**

At this stage every wooden component needs to be inspected, and decisions made about which components can be stabilised and which need to be replaced.

### **7. Repairs**

Repair or replacement of structurally vital wooden components now takes place. Perhaps metal fasteners etc., will also be replaced at this stage.

### **8. Controlling surface rot**

Stopping rot on the timber surfaces. This is the biggest, most important, and probably most expensive part of the project. It often requires rescheduling and waiting to get optimal weather conditions.

### **9. Controlling internal rot**

This is a much more fiddly operation, but at least it is not weather-dependent. Holes may have to be drilled for insertion of boron rods.

There are preservatives other than boron rods that can be used for internal treatment i.e., Boron pastes, Polegel, CN emulsion.

#### **10. Controlling groundline rot**

Rot on piles where they enter the ground poses different problems from rot anywhere else on a wooden structure. Groundline bandaging may be the answer.

#### **12.2 Consolidation**

Hardening of surfaces already softened by rot.

#### **12.3 Obstructing entry of water**

Water repellent treatments will hinder entry of water while allowing exit of water vapour. Other ways of hindering water entry also need to be considered.

#### **14. Subsequent care & maintenance**

Any treated structure needs to be inspected about once a year. Preservative chemicals eventually leach out of timber, and at some stage re-treatment will be necessary.



## 2. ON-SITE SAFETY ISSUES

This manual does not deal with safety issues connected with use of ladders, scaffolding, safety lines, or abseiling gear, or with use of chain saws and other power tools. Minimum protective clothing requirements are gloves, overalls, safety glasses, and the use of others may be required in particular circumstances e.g., respirators and crampons. Wet timber is often more slippery than dry timber, but may be safer to walk about on after algal slime etc. has been removed by waterblasting. Timber recently treated with oil-based preservatives (e.g., CNE) is even more slippery than wet timber. You may find instep crampons useful for moving about on such timber. Tarpaulins placed on the ground which have become covered with a fine mist of preservative from spraying overhead can also be very slippery.

If you are unused to using a powerful waterblaster, get acquainted with it at ground level before venturing up high. There is a quite powerful recoil in the hand piece, and spray suddenly ricocheting off timber right into your face can be very disconcerting!

If preservatives are being sprayed on, it is suggested that not more than two people do spraying at any one time, and that they keep well away from each other, to reduce the chances of one person's overspray drifting into the other person's face. Respirators with appropriate filters should be worn when any liquid is being sprayed.

The preservative chemicals recommended here are not known to be particularly toxic, corrosive or dangerous. Particular safety issues concerning specific chemicals and application techniques are mentioned at the appropriate locations through the rest of the text. More detailed safety information is available in the form of "Material Safety Data Sheets" (MSDS) from the various suppliers. These prescribe suitable antidotes for accidental ingestion etc. Note also: Although the active ingredient in CNE and CNL is of low toxicity the hydrocarbon carriers may cause skin irritation.

Products containing TCMTB, e.g., Polegel, are of low toxicity if swallowed, but can be corrosive to skin (effect is similar to sunburn!), eyes, lungs and intestinal tract (bad heartburn!).

Polegel, because of its viscosity, is fairly safe to use, but it still has a habit of oozing out of the caulking gun right when you least expect it. Take care when driving plugs into insertion holes to ensure that Polegel doesn't get squirted into the face or eyes.

Boron rods are quite safe. The boron compounds in them have about the same toxicity for mammals as common salt.

Solvents used in CNL are highly flammable. Creosote is also highly flammable, and its application considerably increases the flammability of timber for at least several days after application.

Fumes are unlikely to be an issue with the chemicals recommended here, especially out in the open. In confined spaces ventilation needs to be provided when using creosote or CNL. Respirators with appropriate filters need to be worn when creosote is sprayed, and should be available when CNL is sprayed.

Potential dangers with any chemical supplies should be explained to anyone connected with their transport, especially boat skippers and helicopter pilots. Even if you think your chemicals are perfectly safe it is courteous to explain what they are - and the transport operator may be aware of transport-related hazards unknown to you (e.g., lids popping off paint tins at higher altitudes!).

- When mixing two liquids always pour the more dangerous liquid into the less dangerous one (unless otherwise specified by the supplier).
- All chemical containers should be clearly labelled, and ex-food containers should not be used to hold chemicals. (Quite apart from the safety issues, some food containers including plastic milk bottles and icecream containers are soluble in organic solvents.)
- In general, brush-on application techniques are safer (and less environmentally contaminating) than spray-on ones. Boron rods are relatively safe.
- When application of any chemical is underway it is always a good idea to have nearby, as a minimum, a labelled bucket of clean water, a cake of soap and some rags, just in case someone needs to wash themselves down in a hurry. Ordinary mineral turpentine is useful for cleaning up spills of CNL and creosote.
- When using any product the manufacturer's recommendations relating to protective clothing and other safety precautions

### 3. INITIAL ASSESSMENT

Before undertaking any stabilisation work you should do a rough assessment of all aspects of the proposed project, looking at such issues as importance, urgency and feasibility:

- a) Is the structure important enough to be worth trying to stabilise?
- b) How feasible is it to stabilise the structure? Perhaps it is already too decayed to be worth trying?
- c) How urgent is it that stabilisation procedures be undertaken on the structure in question? Are other structures more urgent?
- d) If it is decided to go ahead then some thought needs to be put into issues such as estimating how big the project is likely to be - is it a one year project or a multi-year project?
- e) Deciding on the sequence in which the various operations are carried out - looking at such questions as whether it is necessary to waterblast the structure before detailed inspection is carried out.
- f) Getting a rough idea of how much of the structure can be preserved, and how much needs to be replaced.

The initial field assessment will be carried out by making a visual inspection of the structure. An ordinary screwdriver (not a Phillips head one) makes an excellent probe for getting a rough idea of how extensive and how deep the rot is. You should attempt to identify the timbers involved to be sure that they have sufficient potential durability to be worth trying to preserve.

One important aspect to think about at this stage is access to all parts of the structure. Can all components be reached from ground level or by standing on the structure itself? Or will it be necessary to use ladders and/or scaffolding? Ladders need to rest on something firm and lean against something firm. Scaffolding is expensive to hire and difficult to transport to remote locations. By law it has to be independently inspected every week.

If work needs to be done well above ground level it may be necessary to rig handlines, or use safety lines and a body harness. If the structure is in a deep narrow valley it may be simpler to rig a line across the valley above the structure, and employ abseilers to carry out the work. Abseilers enjoy a three-dimensional ability to move around and over a structure which is hard to appreciate until one sees them in action.

At this stage it may be necessary to get some assurance from a qualified engineer that stabilisation is feasible, and that after repairs and preservation treatment there will be enough fabric left in the structure for it to remain standing, and for it do so without posing unreasonable risks to staff working near the structure or to visitors viewing it. (At the end of the project DOC will require signing off by an engineer anyway, so one might as well be involved from the beginning.)

Potential natural hazards to the structure need to be assessed. Are there large trees that might fall on it? Are rock falls or soil slumps likely to bury it? Could a flood wash it away?

The structure's appearance will be changed forever once waterblasting commences, so take lots of photos beforehand. Some components may be so thoroughly rotted that they will not survive the waterblasting.

### 3.1 ARCHIVAL RESEARCH

Initial assessment will be more realistic if archival research is done now. How old is the structure? How many times was it rebuilt or repaired? What natural disasters (floods especially) have affected it? Was it ever affected by fire?

Original specifications can be fascinating. What timber was originally specified for its construction, and what treatments were specified for the timber? Often the specifications were quite specific. For many structures coal tar was to be boiled for 6 hours, then mixed 2 parts of coal tar to 1 part Stockholm tar, for application to end grain and lap joints. The Railways originally specified red lead primer in joints, and later red oxide/linseed oil paint for end grain.

Original engineering drawings may still be in existence, and are useful for finding out what the original dimensions of components were, and what components have entirely disappeared.

The date when the structure went out of service (i.e., when the railway branch line closed or a modern road bridge was opened) is important as it indicates how long the structure has gone without maintenance. This gives a preview of just how grisly the rot and other mayhem is likely to be.

## 4. CLEANING DOWN

Most structures that have not been subjected to any previous stabilisation treatments will probably be largely covered in dirt, moss, lichen, algal slime and rotted wood. Cleaning down is not absolutely necessary, but surface accumulations can prevent preservative chemicals from penetrating to sound wood. Cleaning down will reduce the amount of preservative chemicals needed to treat the structure.

If the structure is reasonably free of dirt, moss etc. it may be possible to dispense with cleaning down - this will apply particularly to structures exposed to plenty of sun and wind.

Cleaning down need not be too thorough. A few millimetres of weathered or partially rotted permeable wood will help to retain an effective coating of preservative over the sound wood beneath.

### 4.1 WATERBLASTING

Waterblasting is the best method of cleaning timber down to moderately sound wood. Waterblasting is also a marvellous way to discover previously unsuspected areas of rot and other structural weaknesses.

It will generally make more sense to use a petrol waterblaster rather than an electric blaster running off a portable generator. The two most important characteristics of a waterblaster are the water pressure at the nozzle, and the volume per minute delivered. Pressure is usually adjustable, but throughput is not.

Water pressure determines how powerful the water jet is. In general a pressure of 500-1500 psi will readily remove dirt, moss, lichen, and completely rotten wood. Higher pressures are likely to weaken the fabric of sound wood. Experience will indicate what pressure is best - if it is too high an observant operator will soon notice that sound wood surfaces are acquiring a furry texture as individual wood fibres are loosened from their matrix.

Throughput determines the speed at which cleaning down can be performed. Electric-powered domestic water blasters may have sufficient pressure but agonisingly slow throughput. Commercial waterblasters will clean a timber surface in about one fifth of the time needed with a domestic blaster.

Waterblasting is good fun, but it is amazing how soon one becomes chilled by the more or less constant fan of high-velocity water ricocheting off the surfaces being cleaned, even on a hot summer day. At a minimum the operator needs plenty of warm clothing and PVC parka and overtrousers. Wet suits are ideal for protracted operations.

A clean water supply is necessary for waterblasting, to prevent wear on the pump and blockages in nozzles etc.

Most waterblasters have provision for adding detergents or other chemicals to the water flow. For our purposes there is little advantage in doing so, and, given

the large amount of water passing through the waterblaster, any chemicals added at this stage are a potential cause of environmental pollution.

The one big disadvantage of waterblasting is that it injects a substantial amount of water into the fabric of what might otherwise be a reasonably dry structure. Since high moisture content in wood inhibits uptake of most preservative chemicals it is important to schedule waterblasting as early as possible in the overall operation to allow as much time as possible for subsequent drying out.

#### 4.2 OTHER METHODS OF CLEANING DOWN

Cleaning down can also be done using more laborious dry techniques, in particular by brushing down with hard-bristled (and usually long-handled) brooms. It is worth experimenting with a variety of brooms for this. Some brooms clog up amazingly easy with mushy rotten wood. Wire brushes may be useful, but are even more prone to clogging.

Some scraping may also be necessary, using a painter's flat-bladed scraper, especially to remove patches of moss or lichen. A gardener's push-hoe with well-sharpened edge may be effective for scraping larger areas.

Another possibility, particularly for removing dirt and completely rotten wood from fissures, could be a workshop air compressor with hose and nozzle. (If anyone tries this we would be interested to hear how effective it was.)

Dry methods of cleaning may present some minor hazards to the operator by producing clouds of dust. Some early structures, particularly bridges, were coated in red lead primers. These have generally weathered away by now, but red lead may still be present where timbers are in contact with each other. White lead primer is less obvious but just as dangerous. Lead can be detected with sodium sulphide solution (if lead compounds are present the surface will immediately go black when the solution is applied.) If lead is present in quantity respirators with particulate filters should be worn. If there is concern about red lead or other dusts contaminating the environment an ordinary vacuum cleaner can be used.

Other useful tools are secateurs, a tree lopper, and a pruning saw. You may need a spade, shovel, mattock, or crowbar.

#### 4.3 OTHER WORK

Vegetation should be cut back around the structure at this stage to let in as much sun and wind as possible so the timbers have an opportunity to dry out before preservative application begins.

Accumulations of earth, landslide debris, flood silts or gravels should be cleared away from timbers to promote further drying out.

Deal to places where water is ponding on timbers, and where runoff is flowing onto timbers.

Spray penetrating oil on nuts and bolts now in case you need to undo them later.

## 5. PREPARATION OF PLANS AND ELEVATIONS

The structure now has to be given time to dry out from the waterblasting. This provides a good opportunity to prepare plans and sections. There are several possible ways of doing this:

1. From archival sources

It may be that the original engineering blueprints from the time of construction have been preserved in e.g., the New Zealand National Archives (especially for Ministry of Works {MoW} structures). These could be particularly useful for identifying later modifications of the original fabric. Scale is generally shown on old engineering drawings as a ratio (e.g., “one inch equals one foot” so you need to note any enlargement or reduction in the copying process.

2. By adapting standardised drawings

Many old structures, for example New Zealand Rail (NZR) Howe truss bridges, were built from standardised components. In such cases drawings of another similar bridge, or a set of generic drawings for this type of bridge can be copied and relabelled to represent the bridge being dealt with.

3. By direct measurement

The structure can be measured up by taking offsets from a horizontal string baseline with a tape measure, or a compass, clinometer and tape measure. A plane table with auto-reduction alidade will do the job more quickly.

4. By employing a professional

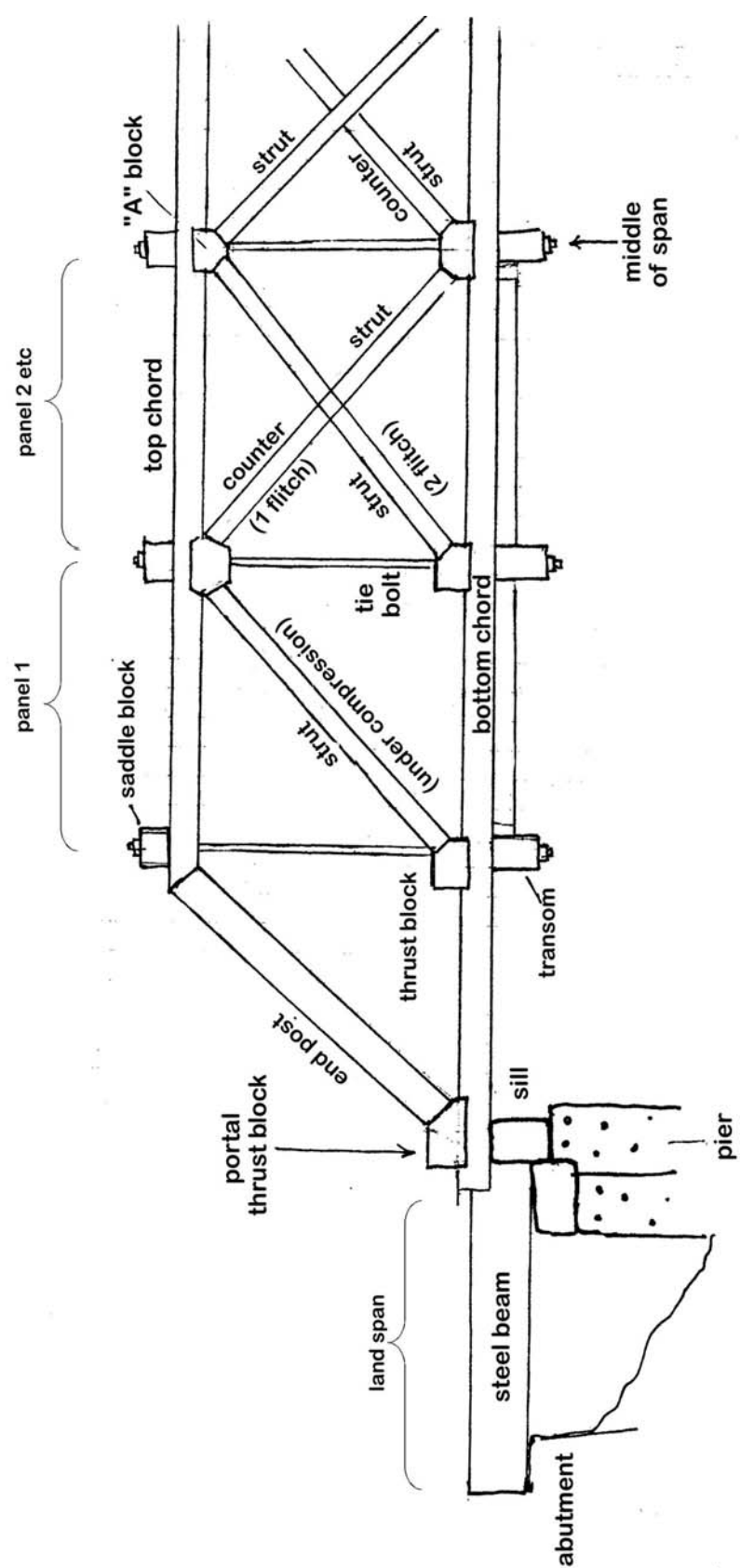
A surveyor or architect can rapidly measure up the structure by theodolite and produce computer-generated drawings. By holding the laser reflector target (or idiot stick) the project manager gets to choose which dimensions and components are measured.

All drawings should show scale and orientation. Orientation can be indicated with a north point, but it is also helpful to indicate which direction is upstream or downstream, and so on.

### 5.1 NAMING AND NUMBERING

This section may sound pedantic but bitter personal experience shows these things to be important.

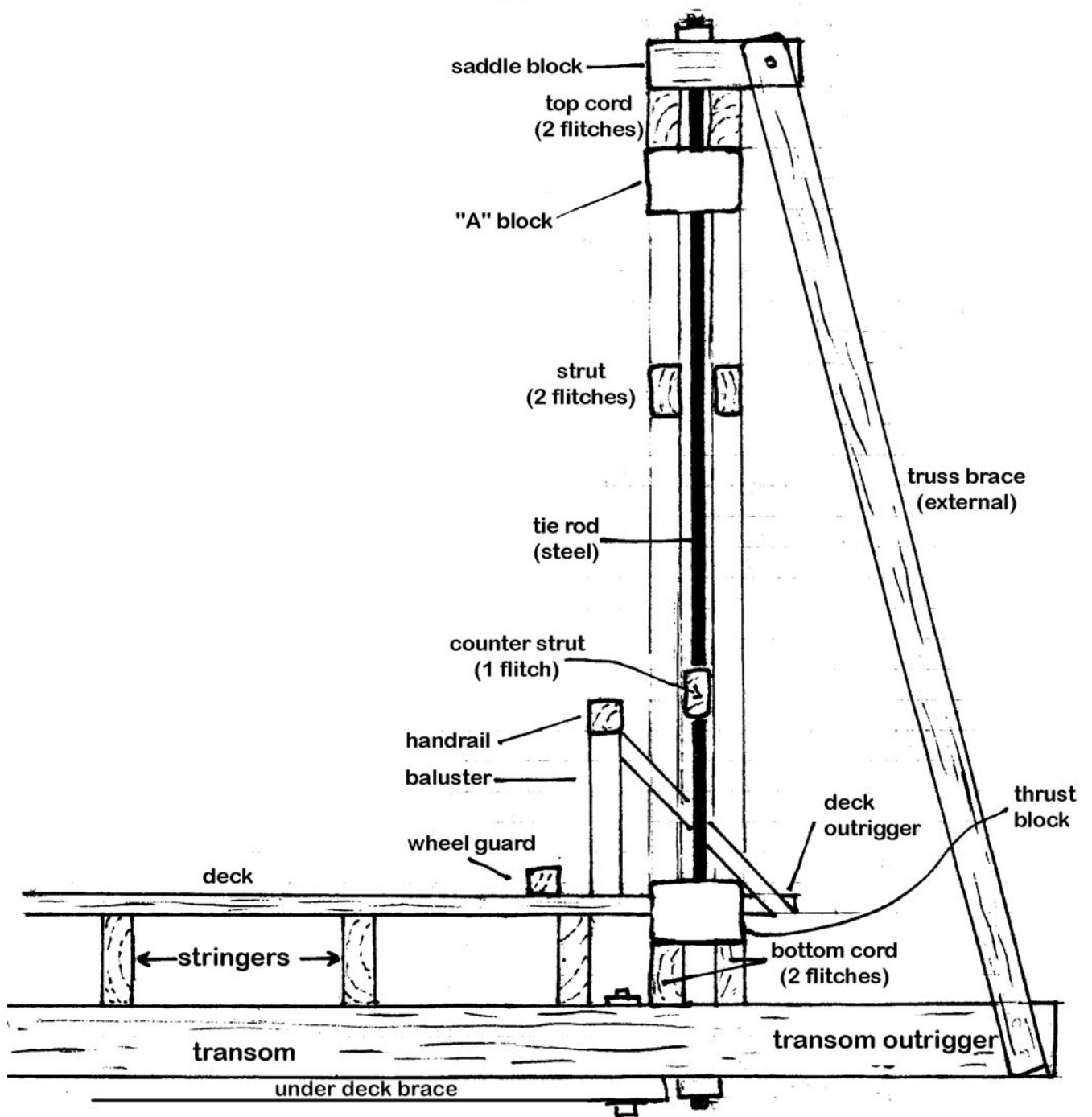
If the structure is a large one made up of repeated substructures (e.g., a multi-span bridge) these need to be numbered on the drawings in some standardised fashion. (The old NZR numbered its bridge spans in the same direction as they measured the mileage on that particular line. A better idea today is to number from true left to true right - see fig. 5. Span one (which commences at an abutment) is followed by pier one which is followed by span two and so on. In a large structure it may be worth physically numbering the substructures themselves



Components of a Howe truss bridge

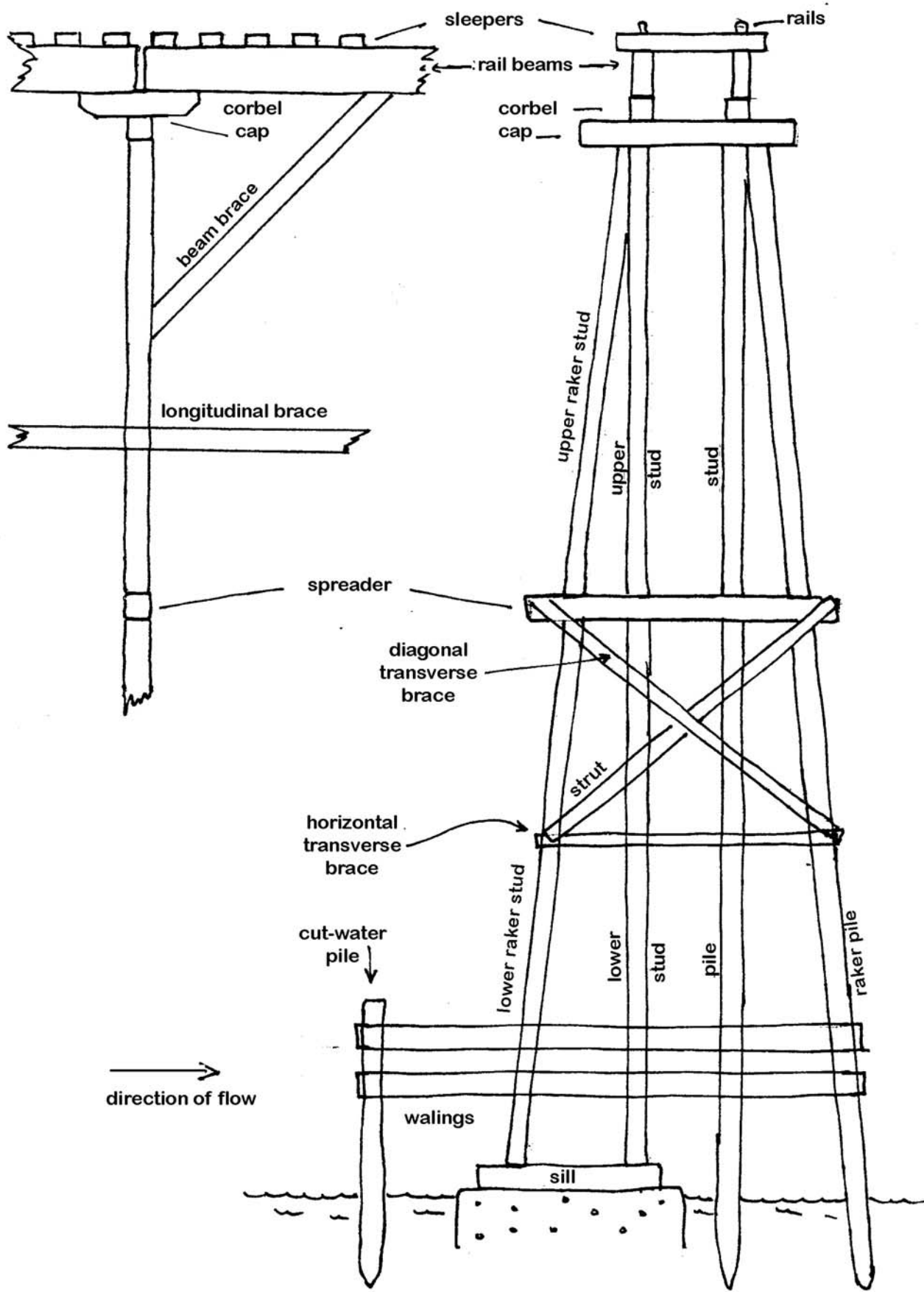
Fig. 1 Components of Howe truss bridge





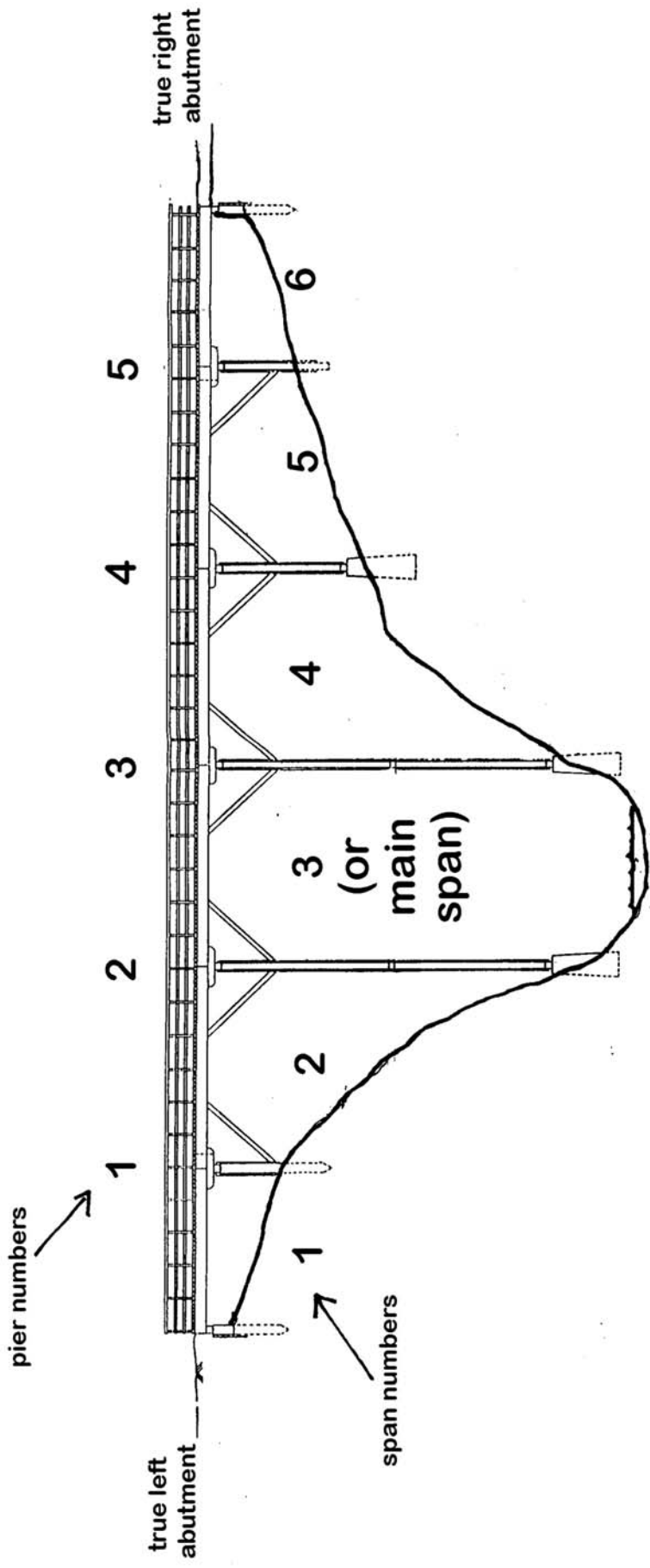
**Details of Howe truss bridge**

Fig. 2 Details of Howe truss bridge



**Components of a beam-and-trestle bridge**

Fig. 3 Components of a beam-and-trestle bridge



Standardised numbering of spans and piers  
(Francis, Burn, Pt. Craig)

Fig. 4 Standardised numbering of spans and piers (Francis Burn, Pt. Craig)

as well, e.g., with plastic cattle ear tags, so there is never any confusion about which trusses, trestles etc. are being referred to or worked on.

Symmetrically paired components on a bridge also need unambiguous identification. Using “left” and “right” relative to the direction of numbering is a bit risky, since it invites confusion with “true left” and “true right” with respect to the river beneath. It is better to distinguish between “upstream” and “downstream” components.

Remember also that (for example) “sloping to the west” is ambiguous - does it slope up or slope down? When describing a horizontal surface you need to specify whether it is an upper surface or an under surface.

Since very few structures are laid out along the cardinal points of the compass it is best to confine the compass directions to descriptions of aspect - “the north side of the pile was less rotten than the south side.”

All this can get quite verbose, but there is no way of avoiding it - “A wood sample was taken one metre above riverbed level from the east face of the upstream true left pile of pier number two”. It’s turgid, yes, but it’s also precise and unambiguous.

Representative examples of the various components should be labelled on the drawings, to encourage everyone involved in a preservation project to use the same names for the same components, and so there is never any doubt as to what is meant when someone refers to, for example, a stringer, a corbel, a lintel, a raker or a thrust block. Some standardised terminology for common components is given in figures 1-4.

## 6. DETAILED INSPECTION, DOCUMENTATION AND PLANNING

The structure has now been cleaned down so that most faults and weaknesses are visible. A good set of measured drawings is available. The time is ripe to carry out a detailed inspection of the structure. The prime purpose of such inspection is to decide which components need stabilising and which components need repair or replacement. Unsound components can be marked on the drawings.

If you are going to seek expert advice on how to best carry out the stabilisation of a structure, then this is by far the best time to obtain it - after the structure has been cleaned down, but before the materials and equipment for preservation have been ordered. The expert can carry out the inspection, draw up specifications for the preservation work, and estimate the quantities of material needed.

Amongst things that need to be done at this stage are the following:

### 6.1 PEERING AND POKING

Climbing all over the structure and visually examining it is the most obvious and important form of inspection. A screw-driver makes an excellent probe for poking into rot to see how soft it is and into fissures to see how deep they are.



Colours and surface textures should be noted. Internal rot and rotted out cavities should be looked for. It may be far more extensive than you first thought [fig. 8].

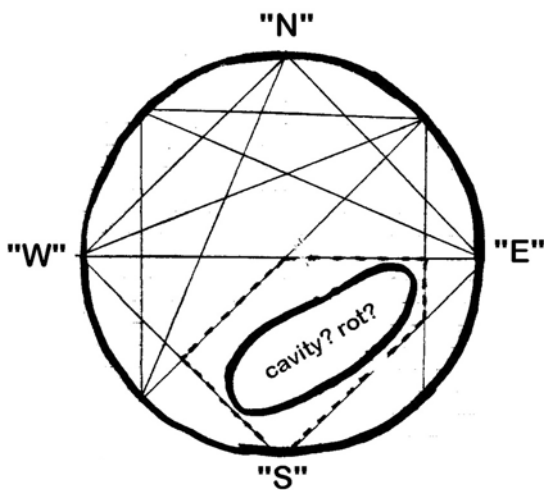
Pay particular attention to timber in the vicinity of nails, bolts, spikes and other fastenings, and wherever holes have been drilled. Fastenings driven vertically into horizontal timbers (e.g., where tramway sleepers have been spiked onto bridge stringers) are a likely cause of serious rot. Load-bearing

Fig. 5: Top chord and strut of a simple Howe truss, showing old inspection holes, some without hardwood plugs. Pukerua Bay road bridge over NIMT.

contact surfaces between horizontal timbers, e.g., where stringers sit on corbels, tend to develop pockets of rot with serious structural consequences.

If lighting is not good it might be advisable to bring a powerful flashlight or, better still, a possum-shooter's spotlight with backpack battery. A small shaving mirror or a motorcycle rear-vision mirror mounted on a stick like a dentist's mirror is useful for examining the undersides of bridge timbers without risk to life and limb.

Probing can be done more scientifically using a pilodyn. This is a spring-loaded device which drives a pin into the timber surface with a constant amount of force. The instrument is calibrated for each job by first of all measuring the penetration of the pin into sound wood on a freshly sawn surface. This distance is then subtracted from all subsequent measurements to give an indication of how deep dozy wood extends. Variation in depth of penetration accurately reflects variation in surface condition of the timber. In general this level of sophistication is not necessary, but it may be called for when an engineer needs to calculate the residual strength in a component with surface decay.



6a Initial scan detects cavity

Fig. 6: Use of ultrasonic decay detectors

In (a) the cavity (or rot) shown will block all rectilinear sound paths except those shown.

(b) Shows the sequence in which data is recorded. The sound source is held against the top of the log, at point N, and the detector is successively placed at E, SE, S, SW and W and the presence or absence of a detected signal is noted. The sound source is then moved to point NE, and the detector is placed at point SE, and so on. When the results are plotted, either manually or by computer, the presence of a cavity (rot) will be suspected in the dashed polygon.

(c) If desired the shape of the cavity can be further defined, and the possibility of smaller voids in the other polygons eliminated by setting the sound source at, say, ESE and WSW and taking two further sounds of measurements.

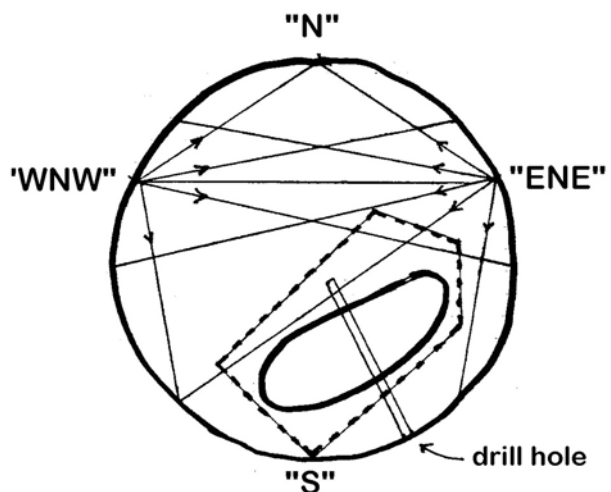
Finally, a single hole drilled as shown will indicate whether it is a cavity, a shake, or a patch of rot which has been detected.

Signal detected ?

	N	NE	E	SE	S	SW	W	NW
N			Y	-	-	Y	Y	
NE				Y	-	Y	Y	Y
E					Y	-	Y	Y
SE		-				-	-	-
S		-	-				Y	-
SW								Y

location of sound source

6b Sequence in which data is recorded



6c Cavity localised with dotted polygon

The old NZR and the MoW originally chiselled onto every piece of bridge timber the year in which that piece entered their yard stockpiles - an accurate indication of how long the timber has been exposed to the elements. In later years only replacement and additional timbers were dated. Timber from one bridge was often re-used to repair another bridge, in which case the timber has two dates - the year it was first used and the year it was re-used, separated by "SH" standing for "second hand". Often the depth in feet to which piles were driven below a chiselled benchmark is indicated by roman numerals.

These marks should be looked for and the dates noted. The results might be surprising. Some timbers might be older than the bridge, having served an earlier incarnation in some other now forgot-ten structure. Some timbers might be much

younger than the rest of the bridge. Often the younger bits of timber are in worse condition than the old bits - thanks to the decline in timber quality over the years.

Besides close-up examination, it is also worth standing back and looking at the structure from a distance, and waiting to see what questions present themselves. Why is there more rot in the left half of the structure than the right? Why is one pile leaning more than all the others? What, if anything, is holding up that high beam I was walking on five minutes ago? (Gulp!) And so on.



Fig. 7: Centre shake on kauri log in the Whitianga Museum. This would be indistinguishable from centre rot in an ultrasound scan. The shake is quite free from rot.

Peering and poking at a structure prior to stabilisation is a bit like buying a used car. There are no hard and fast rules, it is all rather subjective, and the more structures you have looked at the better your judgments are likely to be. It can be done by a project manager new to this sort of thing, but it might be better to bring in someone more experienced. In the latter case the project manager should accompany the expert, to fully benefit from their experience.

Some suggestions on costing and scheduling a stabilisation operation are in section 13.

## 6.2 SOUNDING

A traditional method for discovering hidden internal rot and hollowness in standing timber was to strike the trunk with an eight-pound hammer. At a pinch the back of an axe will do. Sound logs give out a sharp ring, while hollow logs will give out a hollow-sounding thud (obviously). With a little experience internal rot and cavities in piles, beams, sleepers, etc. can all be detected by sounding - particularly useful for locating large internal defects or smaller ones close to the surface. Largely sounding is unsuccessful at locating small internal defects and determining the precise location of internal defects.

## 6.3 EXPLORATORY DRILLING

Generally destructive forms of investigation are to be avoided, but it may well be worth drilling a few exploratory holes into some of the more important structures, in particular to confirm the existence of cavities detected by sounding or scanning [section 8].

In softer timbers (e.g., kauri) this can be done with an increment borer that will remove a continuous core of wood which can be kept in a milkshake straw for future reference. Rot in the core can be detected by pressing with a fingernail. (Increment corers are expensive and easily damaged, but can sometimes be borrowed from botanists or silviculturists who use them for doing tree-ring counts without having to cut down any trees.)

In harder timber it will be necessary to use a twist drill or an auger. Spade bits can be used but they will go blunt very quickly in durable hardwood. The hole should be drilled a centimetre or two at a time, and the shavings removed and examined for rot. The shavings may be worth saving for closer examination later. If they are immediately sealed into a small plastic bag they can be used for determining moisture content. Variations in the speed of penetration will indicate variations in soundness. The depth at which the drill breaks through into any cavities should be noted. If a 14 mm bit is used the hole can be marked with a twig so that it can be used later for insertion of diffusible fungicide.

Holes drilled solely for exploratory purposes should be drilled horizontally or slightly upwards if possible. Afterwards, if they are not needed for diffusible insertion, they should be plugged by driving in at least 5 cm of preservative-treated over-diameter (15 mm) dowel. If the dowel is left protruding slightly the hole can be easily relocated for further inspection.

Bridge timbers will generally have very old 3/8 inch inspection holes in them. [See fig. 5] Some of these can be reamed out with a 15 mm bit to get further clues on what is happening inside large timbers. The very presence of these holes at particular locations in particular components indicates that some bridge inspector in bygone times must have suspected the possibility of internal rot there. A whole row of holes on a particular complement might indicate that the progress of internal rot was being monitored from year to year.



## 6.4 ULTRASOUND SCANNING

This is very simple in principle. An ultrasonic sound source is held against a timber, and a detector is held at various positions around the girth of the timber. Sound waves will not pass through rot or cavities, so the absence of a detected signal indicates rot or a cavity in the sound path. [Fig. 6] By repeating the process while shifting the sound source around the girth it is possible to map out the rot or cavity. Ultrasound scanning is carried out widely in New Zealand to detect internal decay in wooden power poles. The technique works in that it will definitely detect any rot or void in the sound path, but it also has a significant false alarm rate in that it tends to detect faults where none exist. Verification by drilling is not necessary but can help to define features of internal defects.

Both source and detector need to be in contact with sound wood. Alternatively, nails can be driven in deeply enough to encounter sound wood and the source and detector pressed against the nail heads.

The apparatus is expensive and it needs an experienced operator to record and interpret the results. Not all equipment and operators will be satisfactory, so credentials and the ability to produce the desired results will need to be checked carefully.



Fig. 8: A bad case of internal rot in kauri from suspension bridge tower in the Kauearanga valley. This rot was not evident until the post was cut down.

In general ultrasound scanning will not be justified for the sort of jobs we are involved with. There may, however, be some occasions when it can be useful, e.g., to earn a reprieve for a high-heritage-value structurally important component which a consulting engineer wishes to replace because of suspicion about its internal soundness. Ultrasound scanning is likely to be most useful and most effective for establishing the soundness or unsoundness of piles and poles.

A lay person's key to the identification of decay fungi: NZFS information series number 65, 1974. A practical guide to fungal damage of timber and wood products. J. A. Butcher.

## 6.5 GROUNDLINE INSPECTION

In any structure the worst rot is likely to occur where piles and other timbers enter the ground. Rot fungi thrive best in a zone that extends to about 40 cm below ground level. It is vital that at least a couple of piles be dug out to a depth of a half metre or so to see how bad the groundline rot is. It would be preferable if all piles were so inspected. If an engineer is scheduled to visit later the holes should be left open.

Usually it is not necessary to dig deeper than one metre, as very little fungal rot takes place in the near-anaerobic conditions at depth. On steep sites where soil creep and slumping is taking place there may be rot at greater depths. The groundline level may also change in streambeds and on, or at the foot of, slopes.

Sometimes there is amazingly little groundline rot, compared with rot elsewhere on the structure. This is probably because the old-time engineers were often cunning enough to use their very best timbers for piles, and their lower-quality timbers for superstructure.

## 6.6 IDENTIFICATION OF TIMBER AND OF ROT

If the structure is built of durable eucalypt then no further identification is necessary, since all the durable eucalypts react fairly similarly to fungal attack. Identification of durable eucalypts to species level on the basis of timber sample is quite difficult. However, from an engineering point of view, species identification is important in calculating strength.

If the structure is built from native timber now is a good time to positively identify the timbers. Original specifications for the structure may be available from archival sources, or small samples may need to be taken for identification by experts. Knowing what species of timber are present may be important in predicting how long the structure will stand and how safe it is, and may be significant in future preservative treatment or for determining the cause of any failure in preservative treatments. [See Appendix 3]

For identification purposes samples may be taken with a 20 mm chisel. A sliver of sound wood 3 mm thick and 40 mm square will be more than sufficient. Identifications can be done (for a fee) by experts.

For the record it may be useful to know what kinds of rot are present. Brown rot and white rot are reasonably easy to distinguish. Soft rot is a bit more problematical. A layperson's key to identifying fungal infections in wood has been published by the Forest Research Institute Limited. Laboratory identification of fungi to species level is expensive and unnecessary. Deterioration due to weathering (sun and rain) should be distinguishable from deterioration caused by fungal rot. The presence of tunnels made by wood-eating insects should be noted. Size and shape of exit holes can be noted for later identification.

## 6.7 PHOTOGRAPHY AND DOCUMENTATION

Take lots of photos at all stages of a stabilisation project, but particularly before and after cleaning down. The photos can be used to document the extent and severity of deterioration. The remains of components which are to be replaced should be photographed before removal. Any components undergoing structural failure should be photographed. It is worth photographing locations at which investigative holes have been drilled or wood samples taken. Photos can supplement samples for later identification of timber species and type of rot.

Photos are usually best when taken in overcast weather. Use of high speed film is preferable to use of a flash. There should be either a scale, or a person or familiar object present in the field of view to provide scale.

It might be worth establishing permanent photo-points where photos can be taken at annual or greater intervals as part of the long term monitoring of the structure's overall condition. All photographs should be captioned and dated before being filed away. In section 5.1 it was suggested that sub-structures of larger structures need to be numbered. Any such numbering system should be used in the captioning of photos.

Written notes should also be made. These will cover topics such as peculiar methods of construction employed, the distribution of various types or species of timber in the structure, the nature and seriousness of structural faults, and the degree and extent of rot. Photography and note taking may be supplemented by simultaneous imagery and spoken commentary recorded on a home video camera.

## 6.8 PLANNING REST OF OPERATION

Once inspection, photography and documentation are completed detailed planning for the remainder of the project can begin, contractor specifications written, and costs estimated. There are two main issues that need to be thought about.

The first is the extent to which timbers need to be repaired or replaced rather than treated. Decision-making will be based largely on engineering considerations of strength and stability.

The other issue is that of timing. It is crucially important when applying surface treatments that the moisture content of the wood be as low as is reasonably possible. This generally means doing the job in late summer or early autumn. Wood moisture levels tend to lag behind seasonal weather changes, so that even if autumn rains have begun timber moisture levels may well be lower than they were early in a dry summer. Rain, sun, wind and humidity are all important in controlling moisture level, and it may be helpful to consult with your Conservancy fire Technical Services Officer (TSO), who is monitoring these sorts of things all the time. Low timber moisture content roughly equates with high fire risk.

Controlling internal rot is usually less urgent than controlling surface rot. (A 10% loss of diameter on the outside will weaken a component more than a 60% loss of diameter on the inside. See Appendix 2.) But now is the time to decide whether internal rot and groundline rot should be treated at the same time as surface rot, or left until later.

## 7. REPAIRS AND REPLACEMENTS

The process of repairing or replacing components will not be covered in this manual, except in so far as it impacts on preservation processes.

Repairs to a structure can provide access to timber surfaces which are normally inaccessible. Any such opportunities should be utilised to apply liberal coatings of the preservative of choice, in most cases CNE, to surfaces while they are still accessible. Similarly, any new timber should be given a coat of preservative after it has been cut to size and before it is put in place. It is presumed that replacements will be made with timber that is as similar as possible to the original timbers being replaced. Thus kauri will be replaced with kauri of similar vintage, and if kauri is not available macrocarpa is very similar to it. If similar timber is not available then it is probably best to use H4 treated radiata [e.g., fig. 9]. Even this will benefit from a coating of CNE on any cut surfaces.

When repairs are being carried out the need to exclude moisture from both the original and the new fabric should always be kept in mind. If sills are being raised from concrete footings for any reason the opportunity should be taken to insert a damp course in between. Air gaps should be incorporated in vertical joints wherever possible. A length of number 8 fence wire stapled along one of the surfaces to be lapped will keep the surfaces 3 mm or so apart and prevent capillary entry of water and allow some air movement to carry away moisture.

Some of the worst rot in historic structures has been caused by dog spikes driven vertically into exposed horizontal surfaces (e.g., rail spikes, sleeper spikes and deck spikes) - see section 11.2. The use of spikes should be avoided at all cost - they tear open the wood, promote entry of water and generate iron sickness. Bolts in drilled holes cause far fewer problems. Repairs should also be designed wherever possible to avoid the necessity for nailing vertically downward into horizontal surfaces. Wherever possible hot-dipped galvanised fasteners should be used.

Partial replacement is better than total replacement [fig. 10]. If keeping as much of the original fabric as possible is deemed to be important there are numbers of ways in which fabric retention can be maximised. They involve close cooperation between the people doing the repairing and the people doing the wood preserving to make sure that the appropriate preservatives are applied before re-assembly. Some examples:

- If long bridge stringers have to be replaced because of bad endgrain rot it may be possible to cut off the end rot and use the remaining stringer in a span where shorter stringers need replacement - as long as the shortened stringer is well treated with preservatives before being fitted in place.
- If bridge stringers have bad "gutter" rot [see section 11.2] it may be possible to mill them to get planks which can be assembled as box-beams simulating the original stringer. The planks would of course be treated with preservative before assembly. See fig. 11.

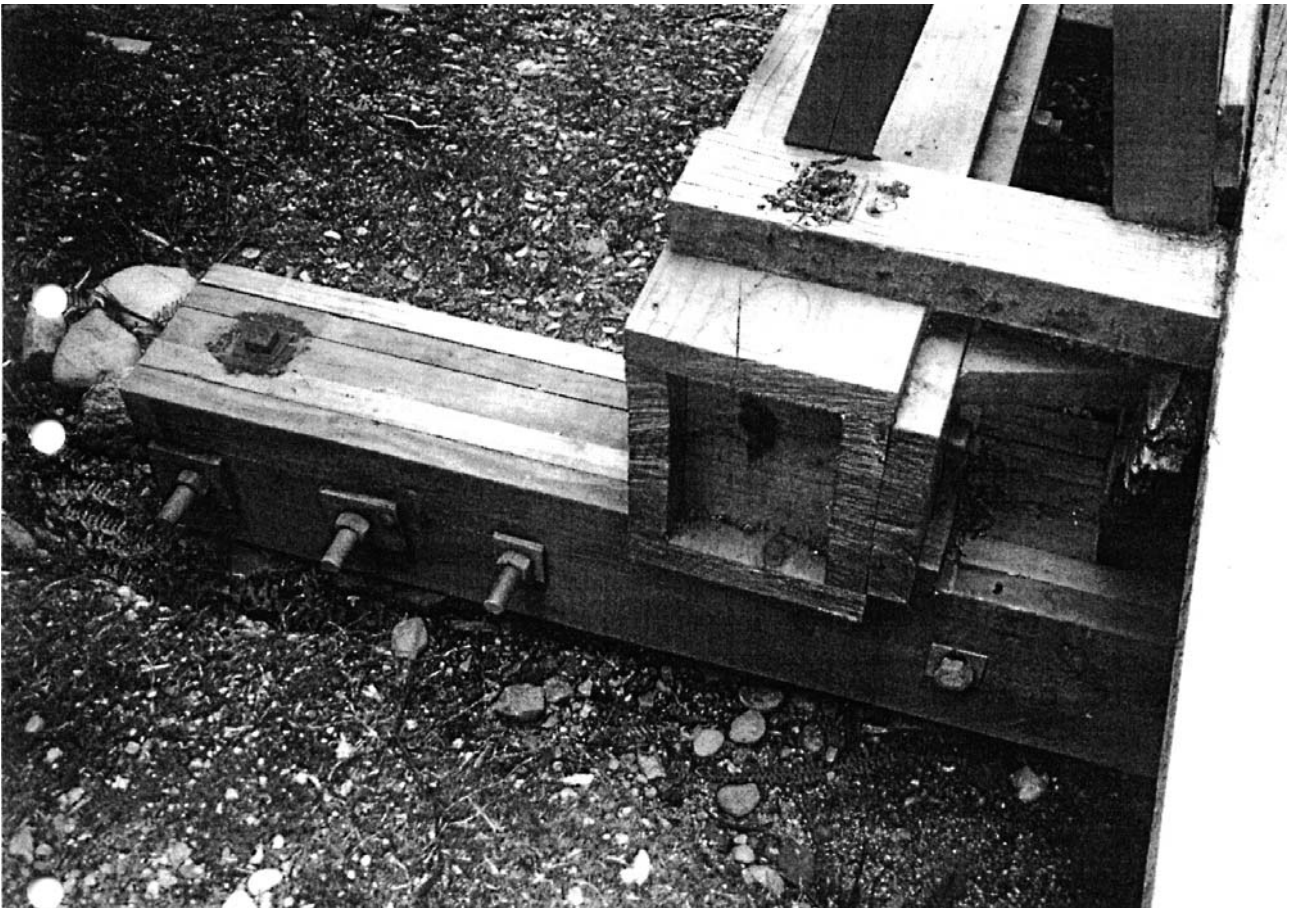


Fig. 9: End of box beam built up from H4 radiata. Note septum resting on laminated radiata abutment. Edwin Burn, Port Craig.

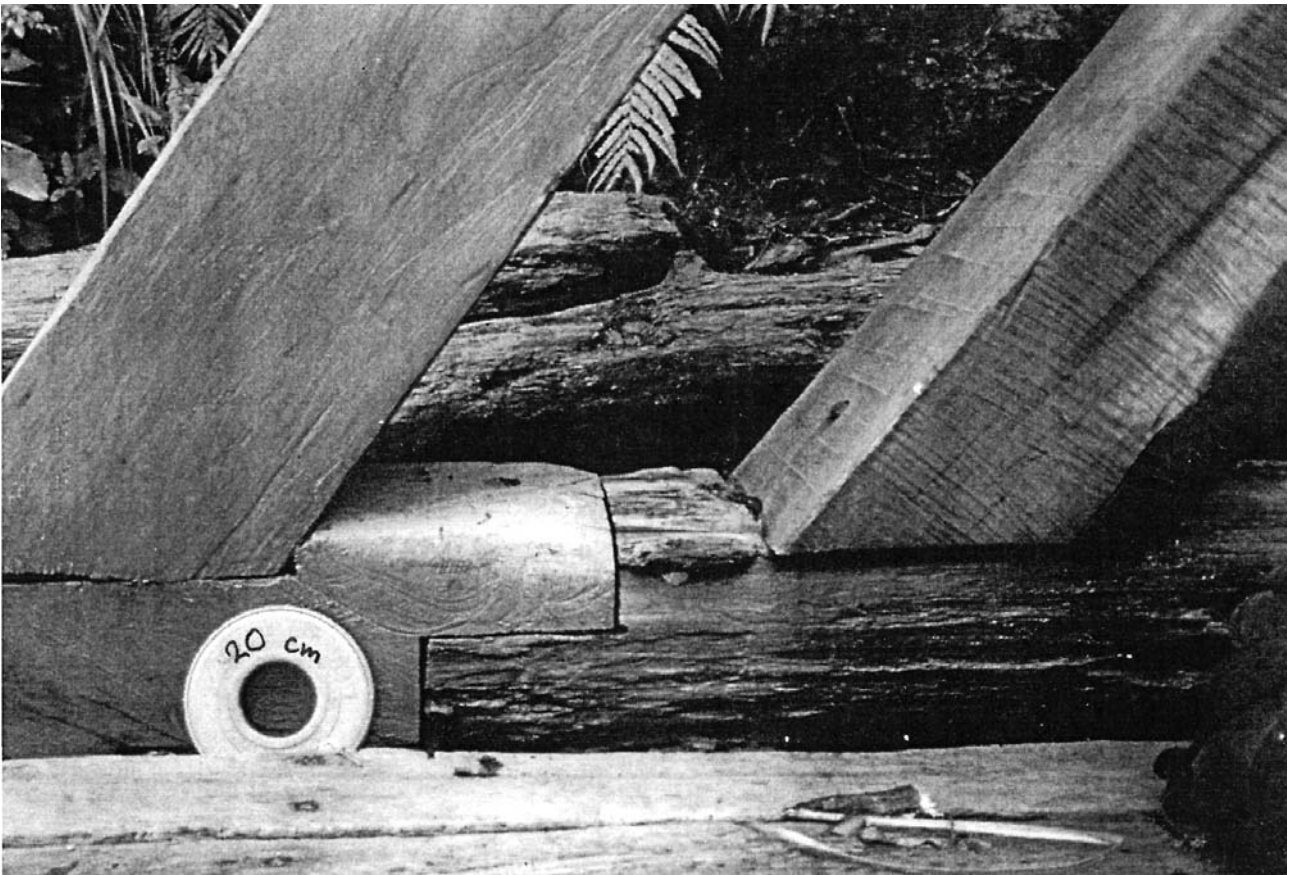


Fig. 10: Partial replacement of gate rafter bracing on Dancing Camp kauri dam. Note half scarf join.

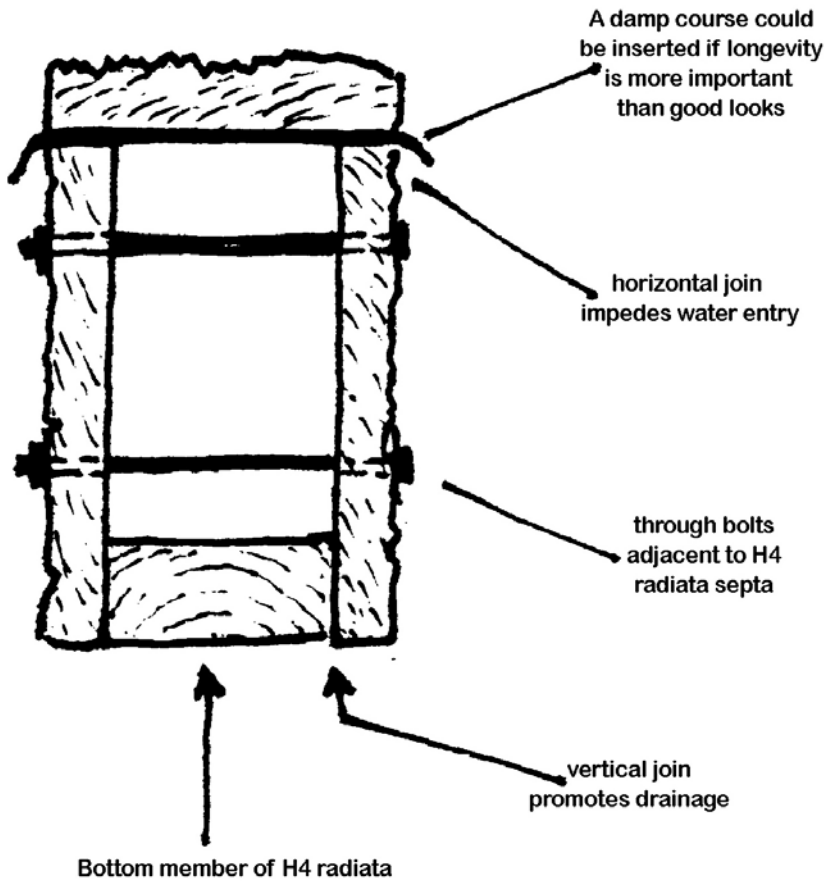


Fig. 11: Box section beam fabricated from sound parts of beam with gutter rot. Compare with figure 9



Fig. 12: Fish plate joining top chord with end strut on a Howe truss. Pukerua Bay road bridge over NIMT.



- If there is bad rot on the ends of some struts in a Howe truss it may be possible to cut off the end rot, and maintain the join between the strut and the chord with fish plates and/or shims. Fish plates were part of the original design on some Howe trusses [fig. 12], so their remedial use today is appropriate.
- If struts have to be replaced it may be possible to get one new strut out of every two old struts by scarf joining.
- Round wood beams and poles, which are starting to bend, splinter, and fracture can be strengthened and given a new lease of life by strapping with stainless steel bands of the type used to fasten street signs to lamp posts, or similar to that used in 'Jubilee' hose clamps. Heavier steel clamps can also be used. [Fig. 13] Get selected preservative into all the splintered bits before the bands or clamps are tightened.

If new components are being fabricated there are several minor changes which can be made to the original design which will help prevent water entry.



Replacement of one component on a Howe truss, for instance, may involve supporting the entire span on false work. If this has to be done, then the opportunity should be seized - with extreme caution - to loosen off all the nuts on the span to allow preservative to be inserted directly onto as many normally inaccessible surfaces as possible, as well as into the bolt holes. Bolts should never be loosened except under the supervision of someone with experience in bridge repair. There is a particular order which must be followed for loosening off and re-tightening bolts on a truss bridge. You need to be absolutely sure there is no stress on any nut which is to be loosened.

Fig. 13: Steel clamp on splintering pile. Sandhill viaduct, Port Craig.

## 8. CONTROLLING SURFACE ROT

The time has now come to coat all accessible surfaces with the preservative of choice, which, as explained in section 1.5, will either be CNE or creosote. As noted in section 6.8 the entire project should be planned and scheduled so that this job can be done when moisture content is as low as possible. The work should not begin if heavy rain is predicted within a day or two of completion. Scaffolding, ladders and pollution control precautions should all be readied beforehand, so that when the right weather comes along it can immediately be taken advantage of. A number of tarpaulins should be on hand, to protect as much of the structure as possible against unexpected showers before, during, and immediately after the work is done.

### 8.1 APPLICATION OF CNE AND/OR CNL

The amount of preservative needed can be predicted by allowing 0.5 kg of CNE per square metre. The amount used will vary enormously depending on surface texture, fissuring, and the depth of dozy surface wood. About 2 kg per square metre should be allowed for end grain, and one kg per square metre to provide an especially generous coating for normally inaccessible surfaces which are exposed during repairs.

CNE has unlimited pot-life, so there is no harm in ordering more than is likely to be needed. The leftovers will keep for the next job.

Precautions need to be taken in advance to minimise the risk of environmental contamination. Given the consistency of CNE - similar to very soft margarine - spillage or drippage is unlikely. CNE is also of low toxicity to most forms of life other than fungi, so a small spill is not of great consequence. The main risk of environmental pollution is wash-off from unexpected heavy rain shortly after CNE has been applied. A decision has to be made as to whether it is better to put tarpaulins over the structure to prevent washing-off, or tarpaulins under the structure to catch wash-off.

If CNL is being sprayed (see below) wash-off is less of a problem than overspray. Spread tarpaulins on the ground to catch overspray and drippage. Dry wood shavings or sand on the tarpaulins can help soak up anything that does come off the structure, and will also make the tarpaulins less slippery if they have to be walked over.

The CNE should be brushed across the grain and into fissures as much as possible. A moderately stiff nylon broom or brush on a long handle will probably be more useful than a paintbrush or roller. It is not necessary to reach right to the bottom of every fissure, as the CNE will “creep” into places inaccessible to the brush, especially in warm weather. The emulsion should be brushed on as thick as the surface layer of dozy wood is deep. It should be thick enough - maybe 2 mm - to leave a visible layer on the surface, which will soak in and disappear after a day or so. Any surfaces which look dry in less than a day should be re-coated. When the CNE has soaked in, the surface will look darker in colour, like freshly oiled timber.



On end grain and on normally inaccessible surfaces CNE can literally be laid on with a trowel. It should be spread 3-5 mm thick, and if necessary given some temporary protection from rain. Ingenuity may be needed to get CNE into tight spaces.

On a well-prepared site the surface coating will go on surprisingly fast. It may take several days to prepare the site, but two people can easily coat a single span Howe truss bridge in one fine day.



Fig. 14: Applying CD50 to Christmas Creek dam. Note wetsuit, abseil gear and long handled roller. Working below one's own body minimises risk of contact with preservative.

If a contractor is employed to apply the surface preservative without on-site supervision it may be advisable to carry out some spot checks afterwards to be sure that total coverage was achieved. Presence or absence of copper naphthenate, the active ingredient in CNE, is very easy to test for, either in-situ on the surface of the structure or in a sliver of wood taken for the purpose. The test area is sprayed with an ammonia solution and then with a rubenic acid solution. If copper is present a black coloration develops instantaneously to the full depth of copper naphthenate penetration.

If desired, samples can be taken for laboratory assay. A 4 mm thick sliver 40 x 40 mm in area taken with a 40 mm chisel will be sufficient. Currently the minimum cost for chemical analysis of copper in wood is about \$110 (up to five samples) and the cost of analyses for other chemicals can be several hundred dollars per sample. There may also be additional sample preparation costs hence it is advisable to get a quote from the analytical laboratory before taking samples.

Keep a record of weather before, during and after application, and of the quantities of preservative used. Make a note of any components which were not treated for any reason, and of any normally inaccessible surfaces which were able to be treated on this occasion.

In perfect weather with bone-dry timber, CNL could be just as effective as

CNE, and somewhat cheaper. It has the potential advantage of being sprayable. Spraying can be much faster if there are large flat areas to be covered (e.g., planking or slab walling) but is likely to be wasteful and environmentally contaminating on structures made up of posts and beams, where overspray is hard to avoid. Ordinary horticultural knapsack sprayers are fine for the purpose, and should be fitted with cone nozzles rather than fan nozzles. The nozzles should be adjusted to produce fairly coarse droplets. Atomisation of CNL results in excessive evaporation of solvent as well as spray drift away from the job and into the surrounding environment.

For similar reasons spraying should not be done in very hot or windy conditions. Rollers [fig. 14] and brushes are best in some locations. The recipe for success with CNL is to keep reapplying it every few hours to all surfaces until it is obvious they are all completely saturated. This hopefully ensures that the CNL has penetrated to the full depth of the dozy surface wood. The need for several applications means that using CNL is likely to take longer than using CNE, where only one application is necessary as long as the thickness of that application is about equal to the thickness of the dozy wood that needs to be impregnated (generally a couple of millimetres). Total volumes of CNL used will be about the same as for CNE if it had been used.

Some CNE should be present on site, even when relying on CNL, to deal with areas that are damp, or where higher loads of preservatives are needed.

## 8.2 USE OF CREOSOTE

Creosote is not widely available in New Zealand and may need to be imported. Emulsified creosote is said to be more “user friendly” than unmodified creosote.

We have very little recent experience in the use of creosote, but in general the use of run-of-the-distillery creosote will be very similar to use of CNL, with more attention to avoiding personal contact with the preservative and avoiding environmental contamination.

We also lack experience in the use of thickened creosote. The likelihood is that it is best applied in the same way as CNE, again with more attention being given to both personal and environmental contamination.

Chemical tests for creosote presence are unnecessary, since its presence is quite obvious to both the eye and the nose.

## 8.3 PREVIOUSLY TREATED STRUCTURES

If the structure has previously been treated many of the procedures described above may be unnecessary, particularly waterblasting - if the previous treatment was reasonably successful and re-treatment has not been put off for too long, there will be negligible growth or rot to be waterblasted off.

You need to decide whether to follow the guidelines in this manual for re-treatment, or whether to repeat the previous treatment. If the previous treatment appears

to have been successful then it is probably best to keep using it, supplementing it where necessary with some of the additional procedures recommended here. This way, we build up a better idea of the relative efficacy of all the available treatments.

If you decide to repeat a treatment using Busan 30L (which is not recommended) then it should be applied at 10% concentration of active ingredient rather than the 1% formerly used. [See Appendix 1]

## 9. CONTROLLING INTERNAL ROT

Internal rot is more difficult to deal with than surface rot. It can be treated at the same time as the surface preservative, or it can be done at any other convenient time - neither weather nor wood moisture content matter. The main way of controlling suspected internal rot is by inserting diffusible preservative into holes, drilled for the purpose, in the timber.

Internal rot will not be present everywhere in the structure - or, if it is, then the structure is probably not worth trying to preserve. Considerable effort needs to be put into the search for internal rot, using the methods described in section 6. Internal rot is most likely to be found towards the ends of timbers.

### 9.1 INSERTION OF DIFFUSIBLE PRESERVATIVES

If internal rot is known to exist in parts of the structure, or if it is suspected to occur then holes should be drilled into those places for the insertion of preservatives which have the ability to diffuse throughout the rotted volume and prevent the rot from spreading.

Holes should be drilled with a 15 mm diameter bit. If drilled from vertical surfaces, they should be inclined slightly below horizontal, and they should not pass more than three quarters of the way through any component.

The most likely situation for internal rot is near the ends of horizontal and inclined components, especially where end grain is not accessible. Holes in such places should be about 10 cm back from the end grain, and spaced about 15 cm apart. Obvious cracks and voids which would cause leakage from holes should be avoided. The presence and extent of internal decay should be determined as much as possible during the detailed inspection and this should be used as a basis for determining where holes need to be bored and how much preservative to apply. Apart from that, choosing where to drill holes, how deep to drill them, and how closely to space them, involves lots of guesswork.

In many places it may not be necessary to drill holes specially for diffusible insertion. Timbers on bridges etc. formerly maintained by the MOW or the NZR were regularly subjected to inspection by drilling. (See fig. 6.) Holes 3/8 inch in diameter were drilled, generally at the ends of components, but also midway along any components more than 3 m long. These holes tend to cluster around any apparent defects in the timber. The holes were supposed to be plugged afterwards, but many of the plugs have since fallen out, and the holes have since served as entry places for rot. Some timbers now have entire constellations of holes already drilled, right where they are needed for internal rot control. As many of these holes as are needed should be drilled out to 15 mm diameter.

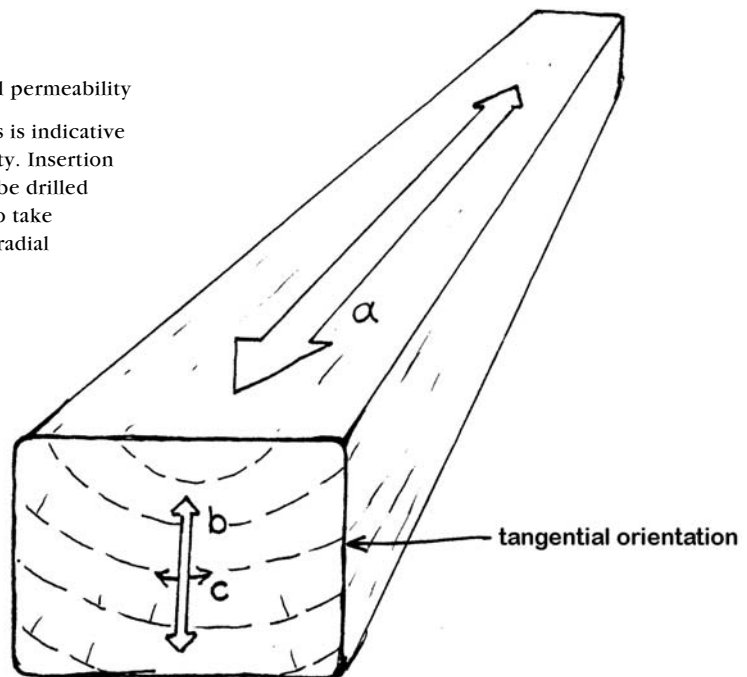
When drilling holes for insertion of diffusible preservatives give thought to the way the grain runs in the timber. Timber is most permeable along the grain, as is well known, so in any hole drilled most of the preservative will diffuse longitudinally. Looking at a transverse section, permeability is much greater

radially (from centre to periphery or vice-versa) than tangentially (around the growth-rings). See fig. 15. This has important implications for the positioning of holes. Holes should normally be drilled as tangentially as possible, to maximise the opportunity for radial diffusion. What this means in practice will become clear if considered in conjunction with the way bridge timbers were cut.

Durable eucalypt logs have a narrow core of pith right through the middle, which is particularly prone to what is known as pipe rot. The durability of the heartwood increases radially outwards from the pipe, so that logs tend quite literally to 'rot from the inside out'. The old-time bridge builders knew about pipe rot, and durable eucalypt, for New Zealand bridges etc., was usually specified as 'free of heart' [i.e., pith] for timbers of cross section less than 8 x 8 inches, and as 'boxed heart' for larger cross sections. See fig. 16.

Fig. 15: Radial permeability

Size of arrows is indicative of permeability. Insertion holes should be drilled tangentially to take advantage of radial permeability.



The idea of this was to avoid having any pipe rot in smaller timbers, and to make sure that in larger timbers any pipe rot was in the middle, where it had least effect on strength. Appropriate and inappropriate locations for diffusible insertion holes in such timbers are shown in fig. 17.

The next thing to consider is the way moisture is likely to be moving within the timber. Water is most likely to be entering from the end grain, bolt holes etc., moving along the grain and passing back out to the atmosphere along all surfaces but especially tangential (i.e., quarter-sawn) surfaces and sun-warmed surfaces. The movement of boron will tend to be similar. If boron rods are inserted near where water enters, there will be a slow movement of dissolved boron away from the entry point, and a gradual accumulation of boron where the moisture is evaporating. Holes therefore need to be drilled close to end grain, on either side of bolts or dog spikes (e.g., in a rail sleeper), and at the shady, damp ends of beams.

The speed at which boron diffuses is dependent on many factors, but moisture content is crucial. The higher the moisture content the faster the diffusion. There will be very little diffusion at less than 30% moisture content. Boron diffusion

will be from highest concentration to lower concentration and will probably be greatest where the moisture content is highest. Therefore in a beam where water is being absorbed at an end and through bolt holes in the upper surface water evaporation may be from the upper and sunny sides whereas the boron may diffuse out to the damp lower and shaded sides. It is probably appropriate to space holes 150 cm apart across the grain, and 60 cm apart along the grain (where necessary). Each 10 cm long rod in theory will preserve about 5 litres of wood, but this is rather meaningless since diffusion is a dynamic process, and rods which diffuse rapidly will be replaced. (Not sure that boron diffusion rates are affected by moisture content over a certain level, check with Kourosh.)

It is quite likely that many of the holes drilled will intersect pipe rot or other cavities. Each hole can be tested by blowing into it, and only those that are airtight should be filled.



Fig. 16: Pipe rot in 'boxed heart' beam. Bridge on Waihi goldfields railway.

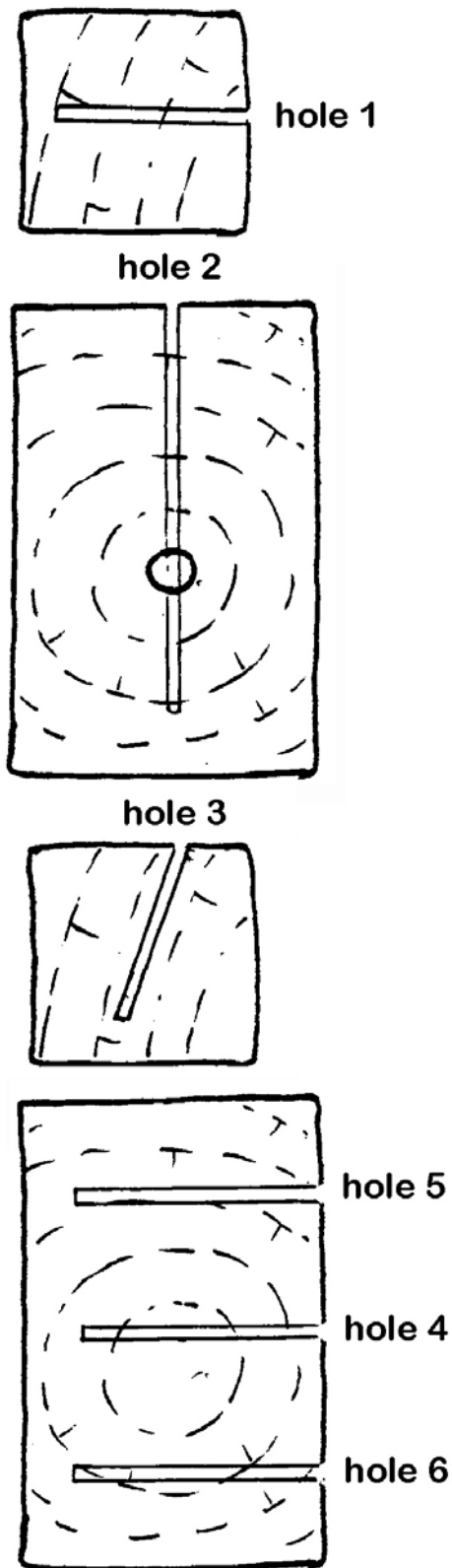


Fig. 17: Drilling holes in timber

Timbers in 'holes' 1 and 3 are less than 8x8 inches and have been cut 'free of heart'.

Beams in 'holes' 2, 4, 5, 6 are larger than 8x8 inches and have been cut with 'boxed heart'.

Holes 1 and 2 are radial and would give minimal diffusion.

Additionally hole 2 intersects pipe rot, and so would leak.

Holes 3, 5, 6 will give best possible diffusion.

Hole 4 will give little diffusion and risks leaks.

Boron comes in the form of fused glass-like rods 12 mm in diameter and 100 mm long. The rods are easily snapped so that each hole can be filled with as many rods or bits of rod as it will hold. Paste is best inserted with some sort of caulking gun or grease gun, fitted with a thin tube which will reach to the bottom of the insertion holes. The threaded plastic plugs are driven in with a hammer (the thread is for removal purposes only).

Each hole should ideally contain both a boron rod and boron paste. Boron paste contains a 'quat' fungicide/surfactant which gives an instant hit, plus glycol which helps the boron to diffuse at lower moisture contents. The rods are a more concentrated source of boron but will diffuse more slowly, and thus maintain the fungitoxic situation initially created by the paste. The general rule is to drill a 15 cm hole, one-quarter fill it with paste, push a boron rod right down into it, and top up any leftover space with more paste. Then hammer in a plug. Any non-airtight holes that seem to have intercepted a sizable void can be filled with foamed preservative [see section 16].

Any holes which are not needed should be filled with preservative anyway, then permanently plugged with over-diameter (16-18 mm) preservative-treated dowelling at least 5 cm long. Most inspection holes will have been drilled radially, so they are not particularly useful for diffusible insertion purposes.

Because diffusible preservatives are on the move all the time within the wood and probably being lost from the wood there is a need to occasionally monitor the status of the insertion holes. The rate at which preservative disappears from the holes gives important clues about what is happening inside the timber. At least some holes should be checked carefully at the first annual inspection [see section 14.1]. The threaded plastic plugs are opened with a screw driver. Holes less than half full should be topped up and closed with a red plug. Holes more than half full should be topped up and closed with a brown plug. During subsequent annual inspections red-plugged holes should be topped up every year, and brown-plugged holes topped up every second year, at least until rates of preservative diffusion are better understood. At some stage further holes may be drilled to allow boron concentrations to be assayed. Depending on the results it may be decided to shorten or lengthen the intervals between top-ups.

## 9.2 TREATING INTERNAL CAVITIES WITH FOAM

Cavities within timber components cause special problems in achieving control of internal rot. Diffusing preservatives are likely to drain into such cavities and be lost. There is no way the internal surfaces can be sprayed with CNL, and it would be prohibitively expensive to try and fill them with CNE.

### 9.2.1 Preservative foams

There is a technique well developed overseas which should be quite feasible in New Zealand. That technique is to inject a foamed boron preservative into the cavity. The foam, with a consistency similar to whipped cream, expands in the cavity and comes into contact with the entire internal surface. Then, over a period of hours the foam collapses against the sides of the cavity, transferring the boron to the adjacent wood.

Fig. 18: Injecting Polegel with a caulking gun.



The holes earlier found not to be airtight have presumably intersected cavities which have developed from pipe rot or other internal rot. Some inspection holes will also have intersected cavities. Further holes may be drilled specifically to gain access to cavities. Other cavities will already have usable openings. All these openings can be used to fill the cavities. When foam starts oozing out of cracks or openings these can be temporarily dammed with clay, building paper or whatever. Knowing how much foam to put in will be largely a matter of guesswork. Holes treated with foam rather than rods/paste can be identified by being closed with a green plug.

### 9.2.2 Foam fillers

It may be desirable in many instances to fill the cavities permanently. This is best done with rigid closed-cell moisture-cured foam. Such foam is long-lasting, unaffected by solvents etc., impermeable to water, and not attacked by insects or colonised by plant growth.



It can restore considerable strength to hollowed-out components. (This is the sandwich - construction principle, in which thin high-tensile strength surfaces are separated by lightweight filler to create very light but very strong objects. Surf boards are a good example.) The polyurethane foam will bond quite strongly to the wooden surfaces, and prevent boron being washed off the surfaces, and it will act as a barrier to loss of any boron diffusing through adjacent wood.

Polyurethane foam is best procured in oversized aerosol cans, for which the price works out at about one dollar per litre of foam. Each 750ml can will give about 20 litres of foam. Because the foam is cured (i.e., hardened) by moisture it is important that all surfaces of the cavity be moist. If necessary they should be sprayed with water beforehand. The foam is then squirted into the furthest recesses of the cavity first, then filled gradually back to the opening. Curing will be hastened by not pouring more than a 10 cm thickness of foam at a time. After the previous layer has become touch-dry it should be lightly sprayed with water before the next layer is poured. Foam surfaces which will remain exposed can be given a smooth hard finish by spraying with water to induce rapid curing before expansion is completed. Polyurethane is reasonably resistant to UV, but exposed surfaces will still benefit from a coat of paint.

Polyurethane foam is wonderful stuff but it is literally a genie which cannot be put back into its can. Once it is out of the can it keeps expanding and expanding, and it will stick to anything, often with unexpected and comical consequences. It is worth experimenting with it on something unimportant and obscure before tackling anything important and high-profile.

# 10. CONTROLLING GROUNDLINE AND WATERLINE ROT

The most vigorous rotting on a structure often occurs where post, poles and piles enter the ground. From ground level to about 20 cm depth is a zone with abundant moisture present for a large proportion of the year. There is also abundant plant nutrients present, and fungi, like other forms of plant life, grow faster where nutrients, especially nitrogen, are abundant. The more fertile the soil the faster the groundline rot. Timber in stockyards, sale yards and gardens is particularly vulnerable. Groundline conditions are particularly favourable to soft rot fungi, which require higher concentrations of CN than are needed to control brown rot and white rot.

According to Swedish research one advantage of using creosote pressure treatment is that, over the lifetime of a utility pole, the creosote, gradually migrates down the pole. When it gets to where it is needed most - the groundline - it is halted by the increased moisture content. Whether this is true of brush-on/spray-on treatments is unknown. Piles driven into shingle riverbeds, waterways and tidal water present special but not insoluble problems.

## 10.1 GROUNDLINE BANDAGING

The principle of groundline protection is to put a thick layer of fungicide in contact with the timber most at risk of attack, and then to keep it there by bandaging with plastic sheeting. The bandage also serves to prevent the fungicide contaminating the soil, and helps to limit the amount of moisture, especially nutrient-rich moisture, entering the timber. Further down in the soil there is very little rot, because there is less nutrient and less oxygen (fungi, lacking chlorophyll, are dependent on atmospheric oxygen), and often because conditions are too waterlogged for fungi.

Groundline pole bandaging is a widely used technique for extending the life of utility poles in New Zealand. [Fig. 19] Soil is removed from around the pole to a depth of about 60 cm, and the pole is cleaned without removing rotten wood. A kilogram or more of Polegel is spread on a sheet of shrinkwrap plastic of size appropriate to the pole. The sleeve is then wrapped around the pole, and the vertical overlap sealed with adhesive tape. A bead of mastic at top and bottom of the sleeve provides a seal with the pole. The entire sleeve is then heated with a gas flame. This softens the mastic and shrinks the bandage tightly against the pole.

In an alternative design three plastic grease nipples are incorporated in the bandage to allow the preservative to be injected after the bandage has been sealed onto the pole. The nipples also allow recharging of the bandage after about 15 years. Preservative may migrate as much as a metre up and down the pole from the bandage.

The technique is eminently adapted to historic structures with large numbers of

piles of more or less uniform size. In such cases it is best done by trained and experienced contractors, and will cost about \$250 per pole, plus the costs of getting the team and its equipment to and from the site.

For some historic structures commercial bandaging will be far too expensive. A small number of piles will not justify the cost of getting the team in place. It is quite feasible, after some trial-and-error wastage of time and material, for DOC staff to do shrinkwrap bandaging. Materials cost about \$100 per bandage.

In other cases the shrinkwrap technique may not be suitable, such as when piles of irregular size and shape in widely varying condition and situation have to be dealt with. The technique is not suited to timbers sitting on hard-rock substrates (for example the rafters in kauri driving dams, see Appendix2).

For such structures it might be worth reviving the more primitive bandaging technique used before shrinkwrap became available. It requires no special equipment or training. Each pile is dug out as before, and cleaned. As much Polegel as possible is smeared onto the pole, which is then bandaged with any thick absorbent material to hand - an old blanket torn into strips would do fine. The absorbent bandage increases the amount of Polegel held in contact with

the pile, and evens out irregularities in the shape of the pile. More Polegel is smeared on. Everything is then spirally wrapped with at least one thickness of 100 mm wide plastic tape, and fastened. This in turn could be spirally wrapped with at least one thickness of Densotape, which binds the whole bandage together, acts as a cushion against impact damage, and gives a low-visibility surface. The Densotape should be smoothed out to make it as impermeable as possible, either to Polegel leaking out, or soil water leaking in. The soil is then carefully replaced around the pole.

The bandaging should extend about 10 cm above ground level. If there are only one or two piles needing groundline treatment then it is not worth buying a pail of Polegel for this purpose alone. CNE is also reasonably effective for groundline protection and is recommended for this purpose by manufacturer Koppers-Arch Wood Protection. The process is the same as for Polegel. Koppers-Arch Wood Protection recommend chipping away any rotten wood with a small hatchet before applying CNE. Thickened boron paste and 'Blue 7' (a diffusing preservative containing fluorine, developed by CSIRO) is also usable.

Not all timbers entering the ground will necessarily need groundline protection. Piles driven into shingle riverbeds may be completely free from groundline rot. Piles in

Fig. 19: Polegel bandage on powerpole, Kopu-Coroglen 10,000 kv line. Note vegetation growing in immediate vicinity, unharmed by Polegel.



waterlogged, clay-rich soil may be experiencing near-anaerobic conditions and have less rot at the groundline than they have above the ground.

One low-technology way of slowing down groundline rot, used extensively for utility poles in Scandinavia, is to excavate to 50 cm depth around the pole, then back-fill with clean coarse gravel. This is reported to have stopped soft rot, which was otherwise eating into poles at the rate of 2 mm per year.

## 10.2 PILES IN RIVERBEDS, WATERWAYS AND SEAWATER

Piles in high-energy shingle riverbeds may suffer from abrasion, in which case they can be protected with neoprene or butynol wrapping, held on with metal bands or wire.

Piles in slow-moving water often decay at and below the waterline through a variety of mechanisms. Rising and falling water levels create ideal conditions for mechanical weathering and fungal action. Constant immersion in moving water leads to natural preservatives ('extractives') being leached out and allows bacteria, both aerobic and anaerobic, to thrive. There are special forms of pole-bandaging, usable underwater, to deal with such situations.

The life expectancy and bearing strength of badly-rotted piles in waterways and lakes can be increased by pouring a concrete cast around the submerged part of the pile. A geotextile 'sock' is placed around the pile, and the sock is then filled with a concrete grout which will set solid underwater. Besides giving strength the concrete creates conditions unfavourable to further rot. Concrete is alkaline, and most rotting micro-organisms prefer acid conditions. The concrete prevents leaching of extractives and creates stagnant conditions in which only anaerobic bacteria will continue to function. Anaerobic decay is generally much slower than aerobic decay.

Piles in seawater can be protected from marine borers by wrapping with heavy polythene or PVC membrane. This is a recognised technique used, for example, on the Marsden Point oil refinery wharf. There are special fastening systems available to keep the plastic taut. Tautness is the important thing. Marine borers, even those that bore into rock, will not bore through plastic, but some of them can slip under slack edges. There are commercial divers skilled in pile wrapping. It looks rather ugly to start with, but generally becomes covered with intertidal growth later.

Marine piles can also be wrapped with a special marine-grade biocide-impregnated petrolatum tape ('Densotape') which can be applied underwater. This has the advantage of being 'do-able' by unskilled workers, and the end result is much less visible than the plastic membranes.

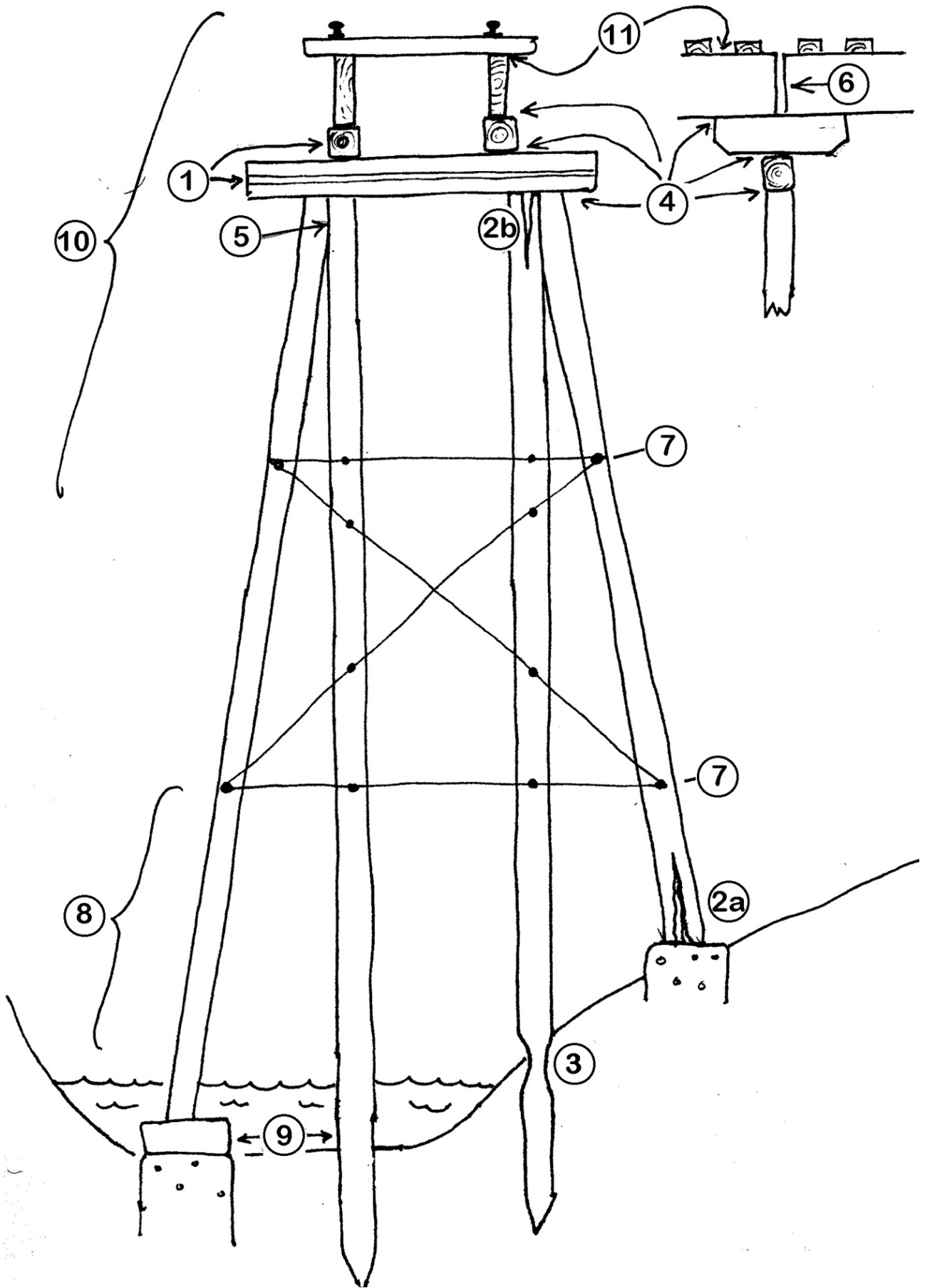


Fig. 20: Key to this image on following page.

Fig. 20: Stylised bridge trestle

On this trestle the following rot/weathering environments may prevail:

1. **Pipe rot.** This is very common in durable eucalypt, but is often of little consequence. Vertical pipe rot is often self-draining, but water may accumulate in horizontal pipe rot. It is not a sign of imminent collapse, and indeed may have been present before the tree was cut down, with little enlargement since. Pipe rot can either be ignored or treated with foam as described in section 9.2. Ideally the foam should penetrate all the way, in which case very long nozzles will be needed.
2. **Butt-end internal rot.** Durable eucalypts in particular often have bad internal rot [2a] at the butt ends. Often this rot was present in the tree before it was cut down. Note that piles were generally driven head down, so that butt end rot can be expected at what are now the upper ends [2b]. Studs were generally erected with butt-end down, in which position it is less troublesome and more easily treated. In all cases the techniques of section 9 are appropriate.
3. **Groundline rot.** See section 10.
4. **Horizontal joints.** Water tends to linger in horizontal joints, especially lap joints (grain parallel to the joint), and rot is often worse here than anywhere else on a structure. See section 11.1.
5. **Vertical side-grain joints.** These are usually self-draining and not a problem. Simply lay an extra thick bead of Polegel along the top of the joint and hope that it creeps in to where it is needed.
6. **Vertical butt joints.** Where timbers are joined end to end. These are subject to endgrain rot which is difficult to get at. Scarf joints can be worse, combining the problems of both lap and butt joints. See section 11.3.
7. **Bolt holes etc.,** do not seem to promote rot as much as one might imagine. Often expansion of the bolt from corrosion is more of a problem. Such expansion can easily split open the wood through which the bolt passes. See section 11.4.
8. **Permanently damp timbers.** The lower parts of a structure located in the bottom of a deep gorge under heavy forest canopy in a high rainfall part of the country may be more or less permanently damp and untreatable with CNE. See section 11.5.
9. **Permanently wet timbers.** For instance, the sill timbers of a kauri dam, are often surprisingly sound. Fungi require oxygen just like any other plant life, and fungal rot will not proceed in totally saturated timber. Pile timbers are generally quite sound below the groundline, for similar reasons (plus the fact that best quality timber was generally chosen for piles). There may be bacterial rot present, but this is much slower. Treatment of permanently wet timbers is not possible, it is usually not needed, and it is recommended that such timbers be left alone. In some situations they can be bandaged [section 10.2]. If there is unsound timber important to the overall integrity of the structure it may eventually have to be replaced (perhaps with H5 treated radiata pine).
10. **Timbers exposed to sun, wind & rain.** Timbers which are not shaded by vegetation, especially in low rainfall, low humidity, high sunshine regions, may be deteriorating from weathering more than from fungal rot. Alternate wetting and drying causes expansion and contraction and eventual breakdown of timber structure. The ultraviolet component of sunlight breaks down the lignin 'glue' which holds the cellulose fibres together. Such timbers will still benefit from the standard surface rot treatment, followed by a water repellent treatment. See section 12.3.
11. **'Gutter rot'**. See section 11.2. The choice of preservative chemicals for all these situations is summarised in fig. 26.

# 11. OTHER SPECIAL SITUATIONS

This manual has now covered the basic techniques of internal, external, groundline and waterline preservative treatments. There are a number of special situations found on historic structures which either require modification of the previous techniques or the use of special techniques yet to be described. An example of such a structure is the stylised bridge trestle shown in fig. 20.

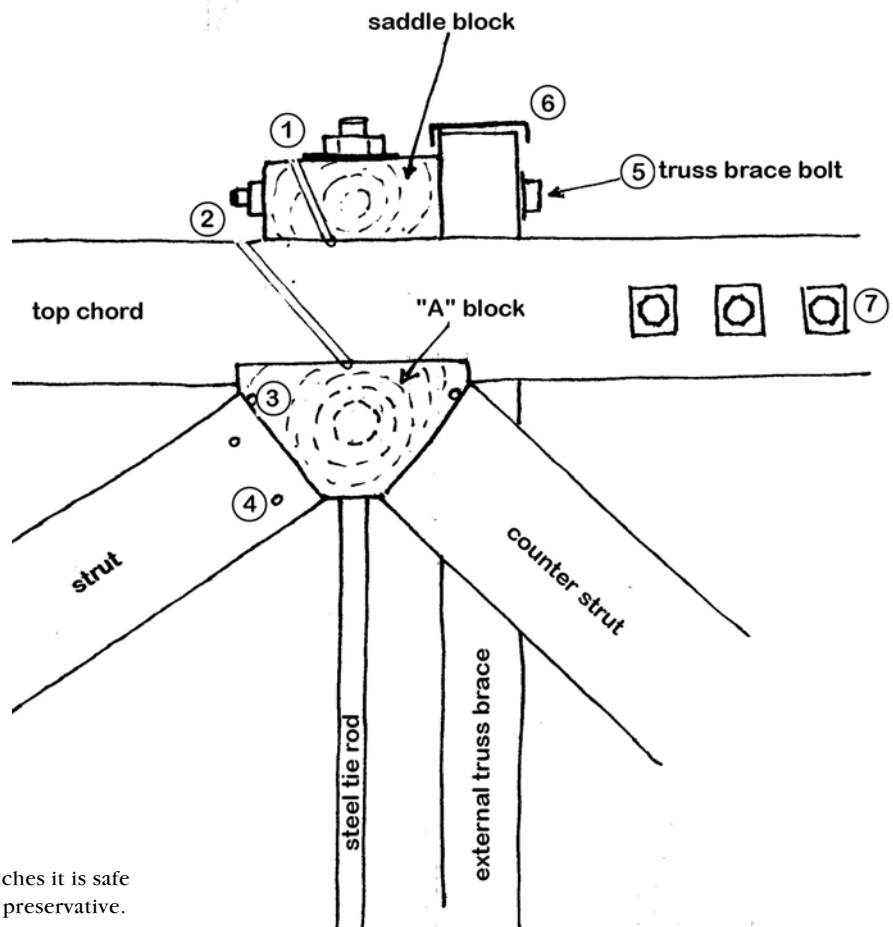
## 11.1 HORIZONTAL (AND INCLINED) JOINTS

Figures 21 and 22 show typical troublesome horizontal joints on, respectively, a Howe truss and a beam and trestle bridge. How it is to be treated depends on whether access to the joint surfaces is possible.

If the structure is undergoing repair, or if for any reason the joint is to be opened up, then it should be allowed to dry out for as long as possible and treated with CNE. Before the joint is reassembled a polypropylene felt impregnated with CNE can be laid on the lower surface, and a bead of bituminous mastic laid round the edge of the felt.

Fig. 21: Horizontal and inclined joints (a)

1. Holes through saddle block get preservative into joints underneath. One hole needed for each flitch in the top chord.
2. Holes through each top chord flitch will preserve joint underneath.
3. Hole drilled in plane of joint to preserve joint.
4. Tangential holes in strut. (If strut is made up of 2 flitches tangential holes probably not possible.)
5. Truss brace bolt can be undone to allow hole to be filled. Under normal conditions there is no strain on this bolt. Only one brace at a time should be treated.
6. A rainproof cap or a heavy dressing of water-repellent will stop water entering the truss brace.
7. Where multiple bolts hold chord flitches it is safe to undo one bolt at a time, to insert preservative. Tighten each bolt before loosening the next.



If the joint surfaces are not going to be accessible there are two possibilities. The first is to ignore the problem. Such joints usually were originally coated with tar and/or red lead. Often they are surprisingly dry and in good condition.

The recommended treatment for such horizontal joints if they look at all dodgy is to drill from above to the plane of the join and force CNE into the hole - until it comes oozing out the edges if possible. If the joint is tight then the hole acts as a reservoir slowly feeding preservative into the join. The greater the area of the join the greater the volume of the hole needed. If the insertion holes are 15 mm diameter, then as a rule of thumb every centimetre of hole depth will provide preservative for about 12 square centimetres of join. The aggregate length of hole can be increased by drilling more holes or inclining the holes. Holes should have colour-coded plugs and be topped up during annual inspections according to the schedule outlined in section 14.1.

In figure 21 [see also fig. 23 and 27] water is particularly likely to enter and linger in the joint beneath the saddle block. The join above the 'A' block is somewhat protected from rain entry but may still be quite damp. The joints between the 'A' block and the struts should be free-draining. Horizontal holes may be drilled as shown if they are thought necessary.

In figure 22 bad rot is likely to occur along the surface between the beams and the corbel. For some reason corbels often seem more vulnerable to decay than other components, probably because of the large number of fastenings passing through them and the high ratio of end grain to side grain. This can be treated by drilling diagonal holes from the sides of the beams as shown in the figure. Other horizontal surfaces are in more sheltered situations and give less trouble.

## 11.2 GUTTER ROT

It is very common to get bad rot along the tops of bridge beams. This rot becomes established through water entering the upper part of the beam alongside the spikes used to fasten decking or sleepers. [Fig. 24].

Corrosion products from the spikes produce 'iron sickness' [see section 11.7]. With time, the rot from each spike spreads longitudinally until the rot patches link up to form a continuous 'U' cross-section of rot. Often its depth and seriousness is not realised until a transverse cut is made through a beam for some reason. Gutter rot often penetrates down to and merges with pipe rot, [fig. 25].

The seriousness of gutter rot needs to be established fairly early in any stabilisation project, so that effort and materials are not wasted on trying to preserve beams that need to be replaced. A technique for fabricating box-section beams which simulate the original beams has been suggested in section 7.1. This can be done with H4 radiata [fig. 9] or with remnants of the original beam [fig. 11]

The only way to preserve beams suffering gutter rot is to dig out as much of the rot as possible, then use copious quantities of preservative to saturate all the remaining rot. Probably the best preservative to use in a situation like this is the bulk boron powder used in commercial boron diffusion plants. This should be sprinkled along the gutter at the rate of 4 kg per cubic metre (4 gm/litre) of wood needing treatment. A water-repellent preservative such as CNE should be



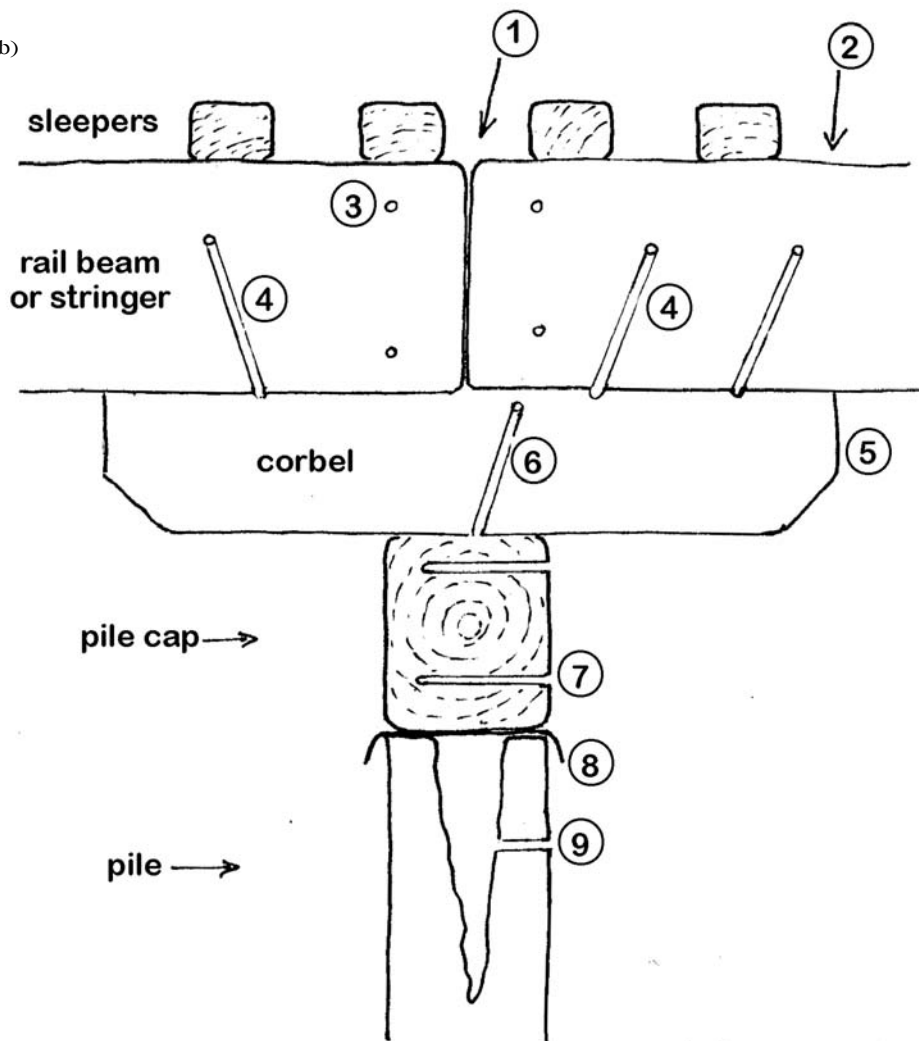
applied to all the outer surfaces to hinder leaching out of the boron as much as possible. All remaining spikes should be withdrawn. Spike holes in dozy timber can be used for diffusible insertion. Any spike holes in still-sound wood should be filled with a flexible silicone filler.

It is worth remembering that the strength of a beam is determined mainly by the depth of the beam from top to bottom and not by what is in the middle of the beam (which is why box section girders can be as strong as solid beams). Gutter rot does not reduce the depth of the beam appreciably and therefore the beam will still have plenty of strength if the gutter rot can be controlled. The main practical problem with gutter rot is that there is practically no sound wood left to attach decking to.

Two possible ways of dealing with this problem are illustrated in fig. 25. Walkway decking is nailed to 150 x 50 H3 radiata bearers bolted onto the sides of the beams. Number 8 fencing wire between the bearers and the beams maintains an air gap. A possible added sophistication is to lay a strip of butynol roofing along the top of the beam beforehand to keep moisture out of the rot gutter. The butynol is held on by clips made from 8-gauge wire rather than nails, and these clips also serve to maintain the air gap.

Fig. 22: Horizontal and inclined joints (b)

1. The gap between the rail beams may have to be widened with a chain saw to allow application of preservative.
2. Gutter rot.
3. Insertion holes to prevent endgrain rot migrating further into beams.
4. Slanted holes for treating rot in join between beams and corbel.
5. Endgrain rot on corbel can be serious.
6. Slanted hole to get preservative on to the pile cap.
7. Insertion holes for pile cap.
8. A damp course to stop water entering pile.
9. Hole for inserting foam into butt-end rot.



### 11.3 VERTICAL BUTT JOINS AND SCARF JOINS

Figure 22 also shows a typical butt join - where the end grain of two beams meet. End grain surfaces tend to rot faster than other surfaces, and end grain rot is often hard to get access to. Before getting too worried about such end grain rot it is worth remembering that the presence of a corbel under such a join is very helpful in that it means the ends of the beams can rot away for quite some distance before there is insufficient sound wood left to transfer the load from beam to trestle.

There are two possible ways of dealing with the situation. One is to dam up the gap between the two beams with putty or even well-kneaded clay, then pour CNE in to fill the gap between the two beams. The other, and probably better way, is to widen the gap between the two beam ends until there is enough room to apply thick layers of CNE, perhaps using a long thin kitchen spatula or a bottle-cleaning brush. This method has the advantage that the chainsaw will remove a considerable amount of rotten wood on which it would not be worth wasting preservative.

For really tight butt joins it will probably be sufficient to lay a bead of Polegel along the top of the join. The Polegel will soon creep down into the join. Scarf joins call for a combination of the techniques suggested for lap joins and butt joins.



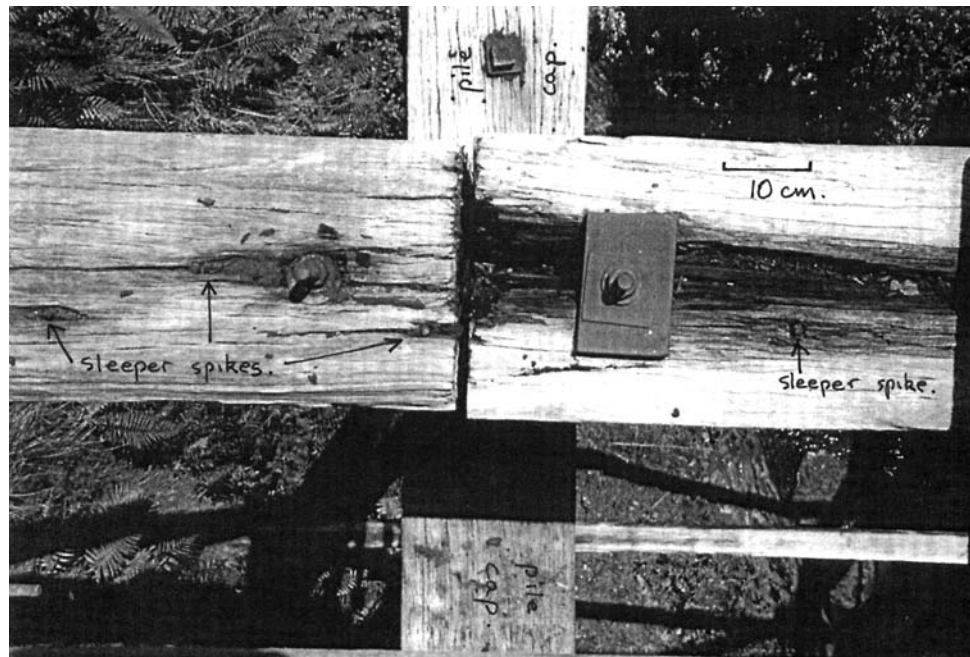
Fig. 23: Top chord and associated timbers on Waikino rail bridge. Note pipe rot on saddle block, upper end grain rot on truss brace. A rainproof cap would have prevented this.

### 11.4 BOLT HOLES ETC.

The holes of vertical bolts are more conducive to rot than those of horizontal bolts, but are also easier to treat. Generally there will be a pocket of rot around the top of a vertical bolt. The rot can be scraped out from under the washer and the pocket filled with CNE. A rust inhibiting hydrophobic grease such as Rescue Steel is probably just as good. There isn't much that can be done about horizontal bolt holes apart from hoping that the internal diffusing preservative in nearby drilled holes will deal to any rot in the hole. Where there are multiple bolts fastening a single joint the nuts can be undone one at a time for filling without any risk of the structure collapsing. Tighten each nut before loosening the next.

Some single vertical bolts can also be temporarily loosened without the structure falling apart. It might be worth drilling a new hole and fitting a new bolt alongside an existing bolt so that the latter can be undone and the hole treated. NEVER undo a nut unless you are quite sure there is no load on it. Howe trusses in particular are highly stressed structures, and it is far better to leave any loosening of nuts to someone who understands those stresses. If bolts etc. are to be replaced or

Fig. 24: Gutter rot  
 Looking down onto rail beams of Francis Burn viaduct, Port Craig. Beam on right has gutter rot just starting round bolt and spike. Beam on right has bad gutter rot. Pile cap, by contrast, is quite sound because it has no spike holes.



added to a structure it is far preferable to use hot dipped galvanised ones.

Neither Polegel nor CNE has any corrosive effect on metal bolts or other fasteners. Boron can actually function as a corrosion inhibitor.

### 11.5 PERMANENTLY DAMP TIMBER

There is not much point in smearing CNE onto permanently moist surfaces, such as heavily shaded sills resting on damp concrete footings. It probably is worth brushing on Polegel. Polegel will be vulnerable to rain until it has entirely soaked in, and temporary protection against rain after treatment could be worthwhile. Gladwrap clingfilm is ideal.

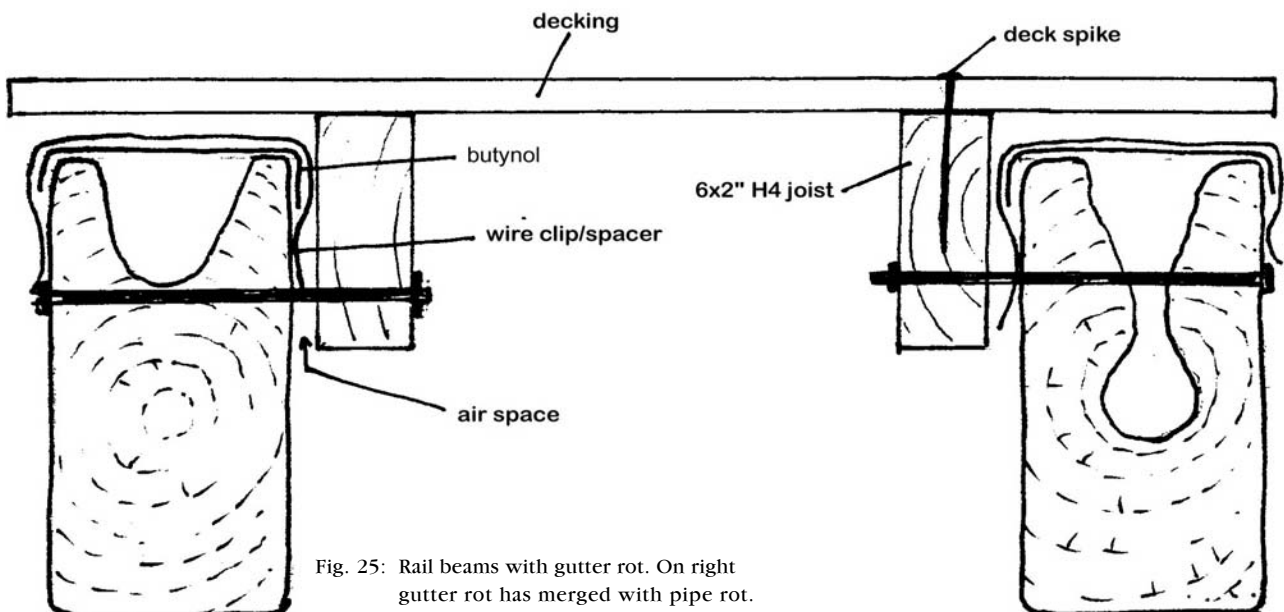


Fig. 25: Rail beams with gutter rot. On right gutter rot has merged with pipe rot.

(Dave Page is not sure "Blue 7" is approved for use in New Zealand.)

Inserted boron will work as effectively in permanently damp wood as elsewhere. The diffusing preservative 'Blue 7', is supposed to be particularly good in permanently damp situations.

None of the preservatives recommended here are known to have any harmful effect on concrete.

## 11.6 PORTABLE, HIGH HERITAGE VALUE ITEMS

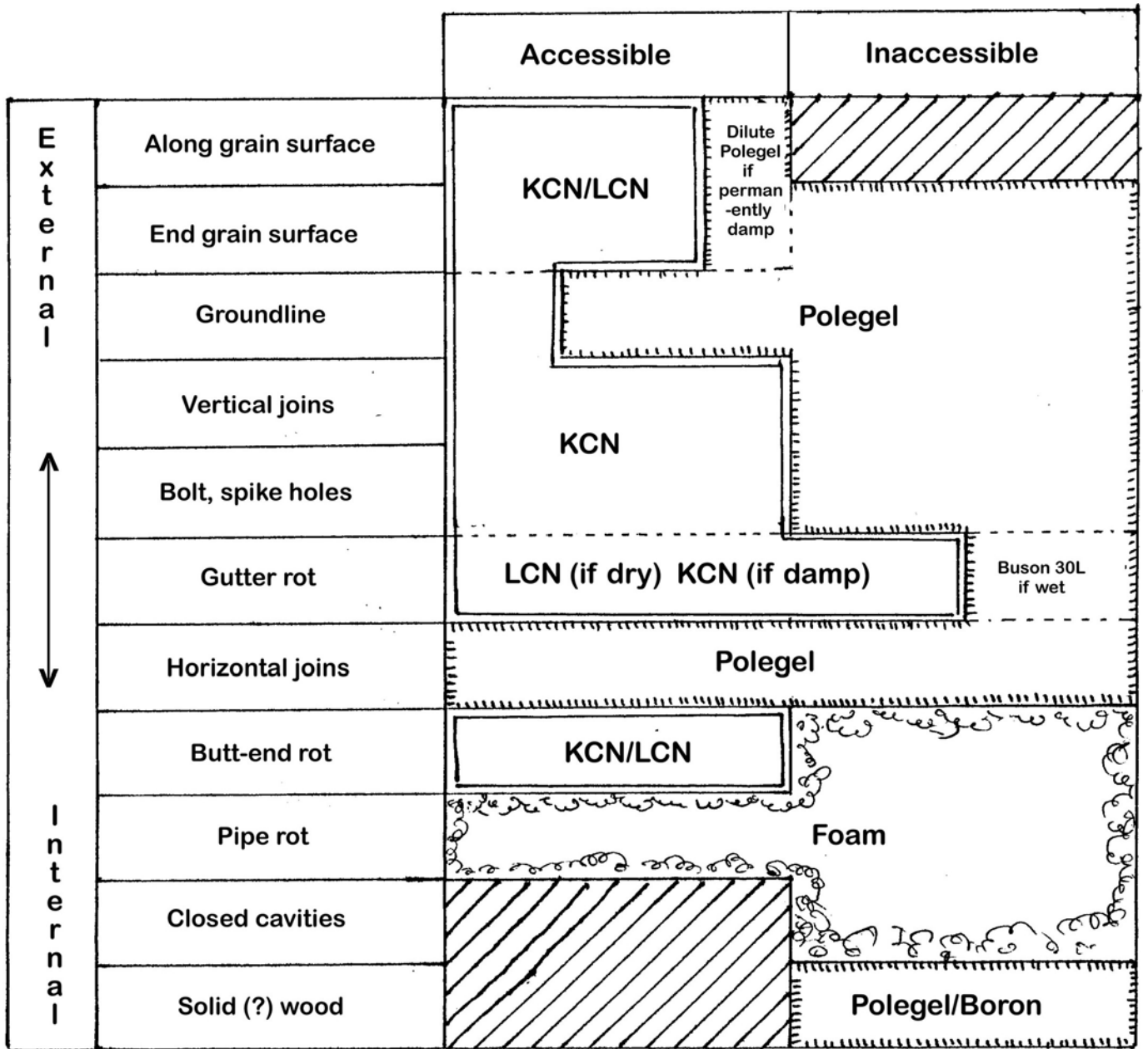
It may be that there is some particularly important component of a structure that deserves special effort to preserve. If that component can be removed from the structure for treatment elsewhere, then there is no reason why it should not be taken to a commercial radiata timber treatment plant and given a conventional CCA impregnation to H4 or H5 level of protection. Pressure treatment is unlikely to have any adverse effect on any reasonably sound timber item, although it would be wise to discuss it with the treatment plant operator, and to experiment first with a small sample or a less valuable component in similar condition. It would probably be necessary to arrange for a much slower pressurisation and depressurisation cycle to prevent implosion or explosion of any closed voids. Timber treatment operators are, in general, reluctant to undertake any treatment that does not comply totally with Timber Preservation Council (TPC) specifications.

(Dave Page: Discussion on susceptibility of very durable timbers to iron rot. A bit speculative. Iron rot and brown rot fungi are often found together.)

## 11.7 IRON SICKNESS

Sometimes an oval zone of blue-black rotted wood is found around iron fittings in otherwise sound wood. Fortunately it is generally not serious in durable eucalypt structures, but it can occur, especially near the coastline. The phenomenon is referred to by shipwrights as 'iron sickness' or 'nail sickness' It is particularly serious on oak and teak-hulled vessels (e.g., the Edwin Fox in Picton). The chemical interactions between ferrous metals and timber are complex and not well understood. There are all sorts of factors involved, including the possibility of galvanic cells being set up between one end of a fastener embedded in wood and the other end exposed to the atmosphere, especially when chloride ions are present. Acid timbers (e.g., teak) are more prone than neutral timbers (e.g., kauri). For some inexplicable reason the less susceptible a timber is to fungal rot the more likely it is to suffer from iron rot. Rot fungi seem to have an inhibiting effect on iron rot. There is only one way to control iron sickness, and that is to stop the iron corrosion. Either remove the offending fixtures and fasteners, or coat them with some corrosion-inhibiting substance.

Corrosion control is outside the scope of this manual, apart from suggesting that fish oil might be as good for short term corrosion control as anything else. See earlier discussion of bolt-hole treatment in section 11.4.



### Choosing between KCN and Poligel



Copper nap. based



TCMTB based



Foam

Fig. 26: Choosing between KCN and Poligel

## 11.8 TOP-END ROT

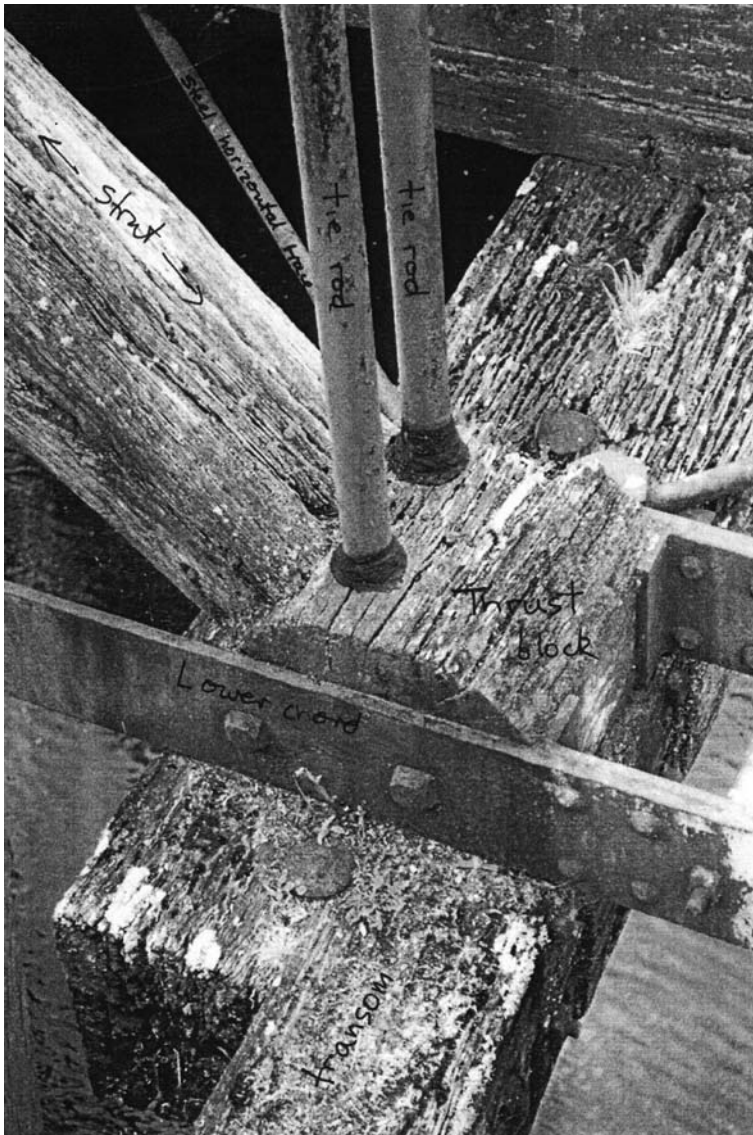


Fig. 27: Flashings on the tie rods protect thrust block in Howe truss with steel lower chord. Thrust blocks are particularly vulnerable to rot and are hard to treat.

Free standing posts and poles are very vulnerable to weathering and rot on the end grain at their upper ends. Water enters via the end grain, and there can be quite deep internal rot and sometimes a rotted-out cavity extending down into the post. Such rot can be treated with a thick layer of boron paste or Polegel on the top of the post or in the cavity, with downward migration of water being relied on to carry it into the pole. If there is a big cavity and a big rotted zone underneath, it will be more economical to throw some boron powder (Tim-bor) into the cavity, as recommended for gutter rot. [Section 11.2]

A waterproof cap should be fixed on all such posts and poles. It needs to be really waterproof - a single nail hole will allow water in while the rest of the cap will prevent water vapour leaving, producing conditions more conducive to rot than before the cap was fitted. The cap should have a slight overhang or 'leave' if possible, and should be fastened with a metal band or with nails driven in from the side. Lead sheeting is probably the ideal material for caps - it is easily shaped, it is inconspicuous, it is very long-lived, it is unlikely to blow off in a gale, it has a fungitoxic effect on the timber underneath, and it is historically appropriate.

A post which is properly capped at the top, bandaged at the groundline, and given regular surface treatments along its length, should last almost for ever.

(The boron powder CNE treatment is new to Dave Page. "I'm not sure that it has been tested. Also I would not recommend the use of sealers in holes, rather fill them with something like CNE and possibly plug them. More research needed here which I will look at with some of the other questions.")

# 12. OTHER TREATMENTS

## 12.1 CONSOLIDANT

Many historic structures in New Zealand have been treated with a 'consolidant' to harden dozy wood so that it has similar wearing qualities to sound wood in such situations as deck planking on footbridges. The consolidant used, formulated by Jack Fry, is a solution of polyvinyl butyral (PVB) resin in t-isobutyl alcohol. Current theory suggests that there is no clear advantage in using consolidant in most situations and that in some situations it may promote rot by impeding the exit of moisture. It may also reduce entry of fungicide during subsequent re-treatment. Theoretically one would expect a buildup of moisture below the consolidant, and a tendency for the consolidated layer to eventually slough off. An effective consolidant could also inhibit uptake of preservative at the next re-treatment. Consolidants are apparently not widely used overseas for remedial treatment of historic structures.

Theory and the overseas technical literature seem however to be confounded by practical experience and results. Several people have used the Jack Fry consolidant and report good results from it. By functioning as a water-repellent, such a consolidant may make an important contribution to slowing down weathering effects [see section 12.3]. The hardening of the surface could reduce mechanical wear on timbers where this is a problem - as with the decking of bridges still in use by pedestrians.

Another consolidant is based on an epoxy resin and has a great reputation amongst people repairing wooden boats. It is, however, quite expensive.

Use of consolidant is not currently recommended for general use, but neither is it proscribed. If it is decided that consolidant is needed - e.g., for deck planking - then it can be bought ready-mixed from Jack Fry, and he can provide instructions for its use. If large quantities are needed it would be better to buy PVB resin (a powder) in 25 kg packs and make up solutions on the job. Acetone is reported to be a better solvent than alcohol.

## 12.2 FILLERS

Apart from the polyurethane foam suggested for internal voids, fillers in general are not recommended, especially for holes on horizontal surfaces. Fillers - for example fibreglass/resin 'bog' and the various silicones - only work when in contact with sound wood from which moisture can be excluded. Such conditions will almost never prevail in the timbers of an outdoor historic structure. Putting filler into wood is like putting fillings into teeth - the hole has to be absolutely free of any rot, otherwise rotting will continue and the filler (or filling) will eventually fall out or lift out. Builders bog really only works on timber which is kept dry by a subsequent 3-coat paint job.

There may be some places on an old structure where there are holes in sound wood which would be worth filling - for examples holes left when sleeper spikes are withdrawn from rail beams. New high-tech versions of old-fashioned bituminous mastics are probably most appropriate.

### 1 2 . 3      W A T E R   R E P E L L E N T S

Water repellents have been little used in remedial treatment of historic structures in New Zealand. There is some experimental evidence, e.g., in FRI graveyard trials, to show that repellents could make a worthwhile contribution to prolonging the survival of historic structures. Further experimentation on historic structures is planned.

Water repellents help prevent rot by reducing moisture uptake in wood thereby slowing down the leaching out of preservatives. By reducing the fluctuations in moisture content repellents are also important in helping to prevent checking and fissuring due to weathering.

Water-repellents intended for use on cedar weatherboards and on patio decking etc. can be bought in hardware shops. Some are solvent-based, some are water-based. All are quite expensive, and they generally confer repellency at the surface for only two to four years. They may provide repellency below the surface for several more years.

If CNE is being used as the surface preservative then at least three weeks should be allowed for CNE to soak in before the repellent is sprayed on. One advantage of CNL is that water repellent concentrates can be mixed into and applied with the preservative itself.

Repellency of a timber surface is easily tested by lightly spraying water onto a dry surface. If the droplets coalesce into tight spherical beads then the repellent is functioning. If the droplets flatten out and soak in then there is no repellency, at least on the surface. It may well be that the repellent is still working quite effectively a couple of millimetres below the surface, which is useful for internal rot control, but isn't much help in stopping surface rot or weathering.

### 1 2 . 4      O T H E R   P R O T E C T I O N   A G A I N S T   M O I S T U R E   E N T R Y

It needs to be stressed that (a) when moisture content (MC) is below 20% fungal activity ceases (but resumes again when MC goes over 20%), and (b) the less water that gets onto or into the wood the less preservative gets leached out. Moisture levels go above and below 20% according to the seasons. The aim of reducing water entry is to increase the amount of time that moisture content is less than 20%.

All reasonable efforts should be taken to reduce the access of water to wood surfaces, and especially to end grain. The end grain at the top of a post or pole can rot nearly as fast as at the groundline. A well-fitted metal cap (nailed on at the sides rather than through the top) can prevent this. Wherever possible, damp courses should be laid under sills. Flashing of densotape or electricians shrink-



tape around the rods on a Howe truss will reduce water entry to thrust blocks [fig. 27].

Nearby vegetation should be cut back to avoid excessive shading. Moss, lichen or other vegetation should not be allowed to grow on the structure, no matter how picturesque it looks. Paint could be another option in some instances, particularly on endgrain. See Appendix 4.2.

## 12.5 MAINTAINING WATERLOGGED CONDITIONS

There may be rare situations in which the best way of preserving a structure is to make sure it stays waterlogged continuously, perhaps by installing a sprinkler or trickle irrigation system. Such situations can be envisaged where timber is too damp to be treated by conventional methods. Kauri in particular seems to last forever if kept waterlogged. See Appendix 4.1.

## 12.6 DAMAGE BY INSECTS

Damage by insects is not generally a big problem on New Zealand historic structures, especially those made of durable eucalypt. Any in-section tunnelling in wood however is undesirable because the tunnels provide access for moisture and rot fungi.

Copper naphthenate and creosote are toxic to insects, but both are toxic to insects. In most cases CNE or CNL alone will be sufficient to control low-level threats from wood-boring insect life. The TCMTB in Polegel also has a strong deterrent effect on insects. Boron is a powerful insecticide at the concentrations recommended here.

If it is believed that additional protection is needed, then permethrin, a synthetic pyrethroid, is reliable, enduring, convenient and cheap. It is about as safe as an insecticide is likely to be. It is usually sold in both oil-miscible and water-based formulations which can be diluted with mineral turpentine or water respectively and sprayed on. Borer generally attack from below so it is particularly important to spray the undersides of beams etc. Permethrin can later be painted over if desired. The oil-miscible formulation can also, be added to CN treatments, but it is hard to see why this should be necessary.

# 13. SCHEDULING & COSTING

## 13.1 TIMETABLE FOR A TYPICAL PROJECT

If we assume that a relatively complex stabilisation project is concerned with a bridge spanning say a 25 m watercourse or some other structure of equivalent size, then the stabilisation operations might be scheduled as follows:

### **Calendar year one**

- January Initial assessment. Two people for one day on site.
- Office: Prepare proposal and budget for business planning purposes. Secure funding for cleaning down structure and making detailed inspection and assessment in next business year.
- July New business year begins.
- November Clean down the structure. Waterblasting is more comfortably done in warm weather. Two people for two days on site
- November Measure up the structure. Two people for two days on site.
- Office: Prepare scale plans & elevations from measurements.
- December Detailed inspection and assessment. Three people for three days on site.
- Office: Make decisions about what to remove & replace.

### **Calendar year two**

- February Prepare proposal and budget for completing stabilisation in next business year.
- July New business year commences. Order timber, preservatives, other materials and equipment. Seek out abseilers and other special assistance.

### **Calendar year three**

- February Repairs. Depending on the state of the structure, this may take anything from two people for one day to five people for seven days on site. Assume four people for four days.
- February Control of surface rot. If weather conditions are suitable this can commence immediately after repairs are completed. If weather is not suitable, other jobs can be done until the weather is right. If weather conditions are completely unsuitable this job can easily be put off as late as April. Assuming conditions are reasonable it will occupy two people for three days (including setting up and dismantling of ladders, pollution control arrangements etc.).
- February or March. Control of internal rot, groundline rot. Internal rot may take two

people two days, pole/pile bandaging will take two people one day for every five piles bandaged. Assume 10 piles = four person-days. In remote locations much time and money can be saved by combining as many operations as possible into each trip.

March Any work with consolidants, repellents etc., should be scheduled at least three weeks after application of CNE. It could very easily be left until the first annual inspection. Two people for two days. There are several ways in which a less complex operation could be telescoped into one business year. For example if the structure is in relatively good condition it may well be possible to do the detailed inspection and assessment right at the beginning, prior to waterblasting. The timetable, it should be noted, is concerned only with what needs to be done to the structure, and is not concerned with such distractions as production of conservation and engineers reports etc. by outside consultants.

### 13.2 OPERATIONAL COSTS

Calculating the likely cost of a stabilisation project is difficult, because it will be done when there is little definite information on how bad all the rot really is. Using the numbers of people and workdays likely to be needed for a medium-sized, but complex, operation the following suggestions may be of some help in budgeting.

Labour Up to 70 person days on site. 50 person days more likely.

Transport Assume a minimum of seven visits to site, involving 14 one-way trips by whatever mode of transport, involving widely varying numbers of people and amounts of gear and materials.

Waterblasting

Hire of waterblaster.

Repairs Will vary from nearly zero to by far the largest expense in the whole operation.

Control of surface rot.

Calculate the amount of preservative required by allowing half a kilogram per square metre to be covered.

Control of internal rot and other 'special situations' [i.e., those situations described in section 11].

Assume two insertion holes needed at each end of each significant component. Multiply number of significant components by four. Add on the number of insertion holes demanded by 'other special situations'. Multiply number of significant components by four.

### 13.3 MATERIAL COSTS

Costs of the main materials/services will work out roughly as follows:

**Control of surface rot (CNE, CNL, or thickened creosote)**

per sq. m. of side grain surfaces \$4

per sq. m. of end grain \$12

Control of internal rot (inserted boron)

per hole (rod, paste & plug) \$3.50

per cubic metre of wood treated \$600

Control of groundline rot (bandaging, Polegel)

per pile done professionally. \$250

per pile, materials for DIY \$100

Retention assays

10 copper assays \$150

10 boron assays \$150

Timber identification, per sample \$80

# 14. SUBSEQUENT CARE AND MAINTENANCE

## 14.1 ANNUAL INSPECTION AND TOP-UP

An annual visit for inspection and maintenance is recommended for any historic structure treated for preservation as described above. Tasks will include

1. Visual inspection for any signs of incipient failure in any of the treated components.
2. Visual inspection for any evidence that the preservation is not successful, e.g., fungal fruiting bodies on treated surfaces. If there are doubts, surface samples can be taken for laboratory assay to determine the concentration of preservative present. A rectangle of surface wood 2 mm thick and 20 mm by 10 mm in area should be taken with a clean 20 mm chisel and put in a small clean plastic bag. Spot-tests are also available for testing for the presence/absence of copper and boron.
3. Top-up red-plugged drillholes every year and brown-plugged holes every second year initially, and less frequently once it is known how fast the holes are emptying. Green-plugged holes (treated with boron foam but not permanently filled with polyurethane foam) should be re-treated with foam every eight years, or whatever time schedule is chosen for re-treatment [section 14.2].
4. Check groundline bandaging to make sure that soil is not over-topping the bandage, and that the bandage is not leaking or damaged.
5. Take photos at the photo points established at the original pre-treatment inspection. Use the same brand and type of colour slide film each time photos are taken, to enable better comparisons to be made from one year to the next. (The colour of colour prints varies enormously from one processing machine to another, and prints are more likely to fade than slides.)
6. Trim back vegetation to reduce dampness on the structure.

## 14.2 RE-TREATMENT

No treatment to prevent fungal rot in timber will last forever. There will always be some leaching out of preservative, and there will always be some weathering taking place which will open new access to untreated wood for decay fungi.

Re-treatment will probably be necessary according to the following schedule:

1. Control of surface rot. Re-treatment will probably be necessary after five to eight years. It should not be necessary to waterblast before re-treatment. If waterblasting is necessary then re-treatment was probably deferred for too long.

2. Control of internal rot. Unless serious new rot has become evident no internal rot control should be needed other than that specified for annual maintenance. Holes which were permanently plugged originally should be checked for loose dowelling and re-plugged if necessary.
3. Control of groundline rot. Bandages may need recharging or replacement bandaging after 10-16 years (i.e., two re-treatment cycles). A decision on when to re-treat could be based on assays of preservative retention levels, as measured by laboratory assay of 20 x 40 x 2 mm surface samples.

Better information about scheduling re-treatment should eventually become available from the Waikino tests. Experience so far has shown that preservatives are lost from upward facing horizontal surfaces about twice as fast as from vertical surfaces, so it may be necessary to retreat horizontal surfaces twice as often.

With any luck, re-treatment will be a relatively cheap and quick operation, carried out at the same time as an annual inspection.

### 14.3 THE NEED FOR GOOD MONITORING AND DOCUMENTATION

It is vital that any preserved structure be carefully monitored, and that detailed documentation about treatments and any continuing deterioration is gathered and kept. The only real way we can ever tell how effective treatments are is to keep looking for signs of continuing deterioration - a pole that has started to lean over, once-firm wood that has become dozy, a crack that has started to widen, and so on. Detailed documentation, especially photographic documentation, will provide the earliest possible warning that something is not right, that something is about to fail, and that something will have to be done about it.

Detailed documentation of the entire stabilising operation will always be important. If we are to identify the cause of a failed treatment we need to know exactly how much of what particular chemical at which concentration was applied by what method, and what the weather was like before, during and after. We need to know all of the same information if we are to improve future treatments on the basis of past experience.

There is going to be continuing pressure from the VAMpires, OSHtocrats and other safety czars within DOC to mutilate or demolish historic structures on the basis of perceived but not necessarily real safety issues. If you can produce the documentation to show that a particular suspect-looking beam has actually been sounded, sampled, scanned, drilled, drenched and drained, and that it hasn't got any worse in the past ten years, then you have a good chance of persuading an engineer not to replace it with some monstrosity of tanalised radiata or steel RSJ.

# APPENDICES

## 1.00 PRESERVATIVES USED IN REMEDIAL TREATMENTS

Copper naphthenate an organometallic compound of copper and naphthenic acid.

Colour Bright green

Acute toxicity: LD<sub>50</sub> >5000 mg/kg, dermal LD<sub>50</sub> >2000mg/kg

Efficacy: Broad range activity against wood decay fungi and wood destroying insects.

Solubility: Readily soluble in hydrocarbon solvents, very low solubility in water. Relatively stable and leach resistant in wood.

Use: Used here and overseas with oils to treat utility pole, in light organic solvents as a preservative (LOSP) for timber uses not in contact with the ground, probably best known as the brush-on preservative "Metalex" green.

Oxine Copper an organometallic compound of copper, also known as copper-8-quinolinolate

Colour Pale green

Acute toxicity: Oral LD50 4000mg/kg

Efficacy: Broad range activity against wood decay fungi and wood destroying insects.

Solubility: Very insoluble in water and most organic solvents. Oil soluble and water-soluble formulations have been developed. The water-soluble formulation is corrosive to metals. Stable and leach resistant in wood.

Use: Principally in water-soluble formulations as an antisapstain treatment for freshly sawn timber. Used in oil-based formulations as a preservative treatment for above ground applications overseas. The fungicide in CD50.

Copper quinolinolate is the only timber preservative that is OK for food-preparation surfaces

Busan. Various formulations of 2 (thiocyanomethylthio) benzothiazole (TCMTB) an organic biocide.

Acute toxicity: Oral LD<sub>50</sub> 1590 mg/kg

Efficacy: Broad range activity against wood decay fungi and wood destroying insects.

Solubility: Readily soluble in hydrocarbon solvents, very low solubility in water. Emulsified formulations generally used. Relatively stable and leach resistant in wood.

Use: Emulsion formulations used for antisapstain treatment of freshly sawn wood and occasionally as a surface applied

preservative. Busan Pole-Gel is used in bandages for the treatment of groundline decay in utility poles.

**Polyphase** . An organic biocide 3-iodo-2-propynyl butyl cabamate (IPBC).

**Acute toxicity:** Oral LD<sub>50</sub> > 1580 mg/kg, dermal LD<sub>50</sub> > 2000 mg/kg

**Efficacy:** Broad range activity against wood decay fungi but not effective against wood destroying insects.

**Solubility:** Readily soluble in hydrocarbon solvents, very low solubility in water.

**Use:** Principally used as a mouldicide in coatings, as a component in antisapstain formulations for treatment of freshly sawn wood and as a fungicide in LOSP formulations for treatment of wood in above ground applications. The active ingredient in Woodlife II.

**Boron.** Various compounds based on borax and boric acid which form boric acid in the wood.

**Acute toxicity:** (disodium octaborate tetrahydrate) Oral LD<sub>50</sub> > 3000 mg/kg, Dermal LD<sub>50</sub> > 5000 mg/kg

**Efficacy:** Broad range activity against wood decay fungi and wood destroying insects.

**Solubility:** Soluble in water. Will diffuse readily into the sap wood of most timber species and will also leach out in wet conditions.

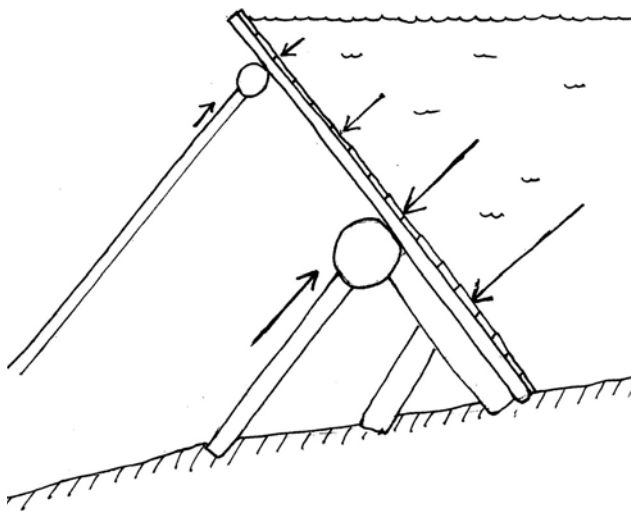
**Use:** Widely used for the treatment of framing timbers in New Zealand and in remedial and insect preventative treatment of structures in other countries.



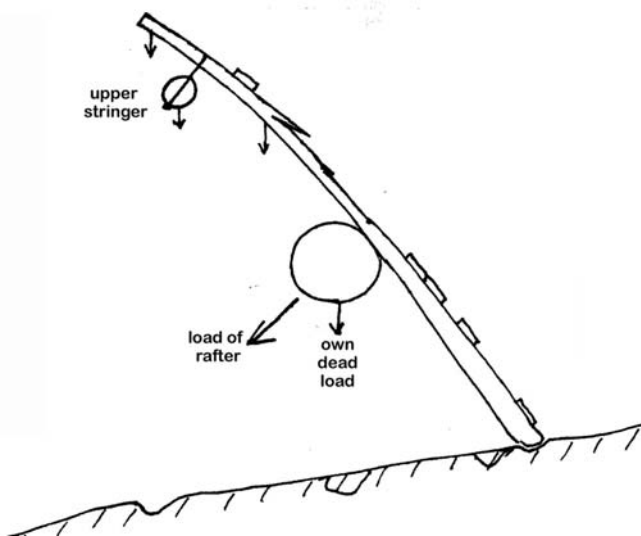
## 2.00 Kauri driving dams

Kauri driving dams pose special problems in timber preservation. The following notes and diagrams are concerned with so-called rafter dams, in which the rafters are upstream of the stringers and carry the horizontal planking. The same principles apply to stringer dams, in which the stringers are upstream of the rafters and carry vertical planking.

Fig. 28: Driving dam loads



a) Full



b) Empty

Driving dams were designed to withstand a powerful lateral force - the hydrostatic pressure generated by the water on the upstream side of the dam. Inclined backlegs were built downstream to oppose the hydrostatic pressure, and the plane of the dam was inclined upward and outward to prevent the combination of hydrostatic pressure and opposing resistance of the backlegs lifting the dam out of its footings [fig. 29]. Unfortunately the backlegs were generally made from inferior timber, and most of them have now rotted beyond recovery. The now-empty dams today constitute highly asymmetrical structures ill-designed to withstand the vertical dead loads they are subjected too [fig. 28].

This situation is aggravated by the condition of the upper stringers. In service these had to withstand less hydrostatic pressure than did the main stringer, so originally had much less diameter than the main stringer, even though they had to span a greater width of valley than the main stringer [fig. 30a]. To achieve the necessary length the dam builders had to leave more of the butt-wood and head-wood than is desirable [fig. 32]. Much of the head-wood was sap, and has now rotted away completely, while the butt wood is prone to butt-rot, so that upper stringers nowadays are badly rotted at both ends and are not even carrying their own deadweight, let alone helping to hold up the rest of the dam [fig. 30b].

The normal situation now is that the weight of the upper stringers is being carried by the rafters, which

means they are being bent downstream and are likely to snap, while the aggregate weight of the upper stringers plus the rafters and any planking is mostly being carried by the main stringer.

The main stringers originally carried by far the greatest hydrostatic load and, in addition, had to withstand all the stresses from the gate suddenly opening and logs smashing their way through whenever the dam was tripped. They were therefore made from massive logs of good quality, with butt wood and head-wood removed. Even so they are now starting to show the strain of carrying the deadweight loads for which they were not designed. An examination of most

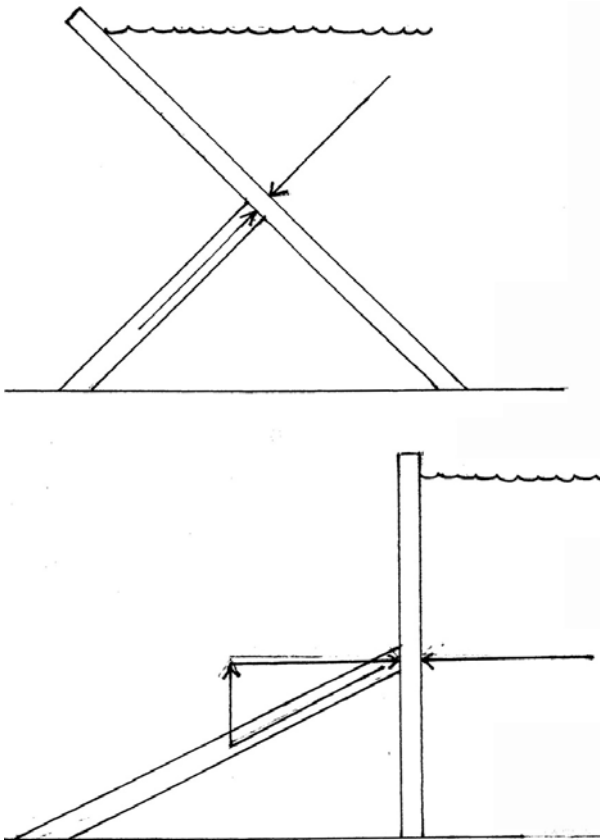
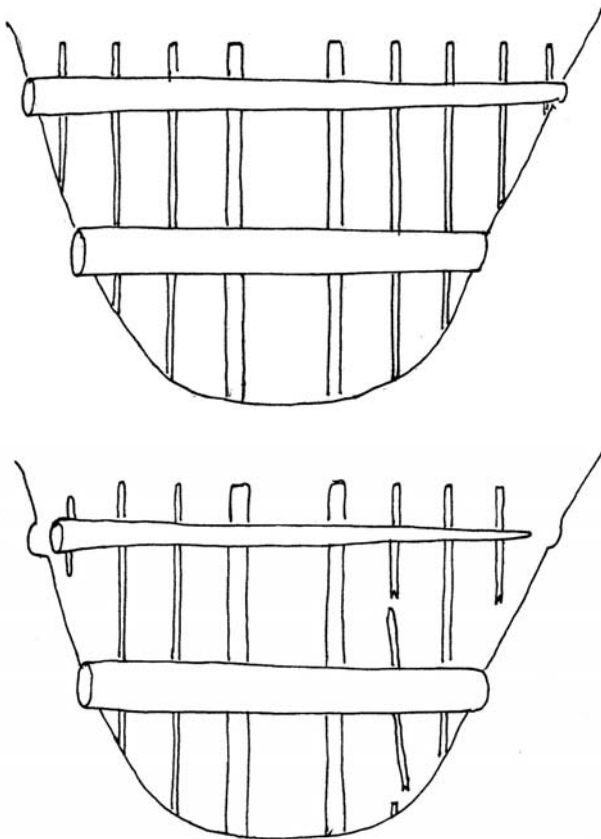


Fig. 29: Dam hydraulic pressure



Figures 30a & 30b: Dam stringers

of the still standing and recently collapsed dams in the upper Kauearanga valley shows that after flood and landslip damage the principal mode of failure in kauri dams is rupture of the main stringer, generally by a long diagonal splintering fracture. Once the main stringer fails the entire dam is lost.

The most urgent need by far in any stabilisation operation with kauri dams is to relieve the main stringer of as much deadweight as possible and then to start pre-serving as much of the main stringer fabric as possible. The quickest, easiest and cheapest way to relieve dead load is to prop the main stringer from underneath. A better way of doing it, in keeping with the original design of the dam, is to install new backlegs for both the main stringer and whatever remains of upper stringers. Back-legging the upper stringer will also relieve the bending loads on the rafters, and will thereby remove some load off the main stringer. (On stringer dams the backlegs will support the rafters directly and the stringers indirectly.) Old power poles may be available to use as backlegs, otherwise H4 roundwood poles will do - they have the big advantage of being lighter.

The gate planks, hanging from unsupported middle of the main stringer, are a real killer. Even worse the line of big staples that hold the wire ropes to which the gate planks are attached provides the potential line of weakness for splintering to occur. There needs to be vertical propping up of the stringer, either using the gate planks themselves, or putting in a couple of unobtrusively-positioned acro-props.

The next most urgent task is to provide as much internal preservative protection for the main stringer as is possible. Rot will probably be worst at the butt end, where the stringer is likely to be hollow for some distance.

A hollow stringer can still have considerable strength. Hollow cylinders in theory are nearly as strong as solid cylinders, and have much less intrinsic deadweight. With a hollow log it is much more important to prevent reduction in the outside diameter of the log than to prevent enlargement of the diameter of the internal void.

The theoretical loss of strength due to rot on external surfaces compared to rot on internal surfaces is as follows:

% reduction of external diameter	remaining % original strength
10	73
20	51
30	34
40	22

centre rot as % of original diameter	
10	100
20	100
30	99
40	97
50	94
60	87
70	76
80	59

In other words a hollow equal to 70% of the outside diameter causes less loss of strength (24%) than does the loss of a mere 10% of the outside diameter itself (27% strength loss). The principal aim of preservative application therefore must be to prevent loss of external diameter, along the entire length of the stringer, but particularly at the ends. This is the case whether or not internal rot or a hollow is known to be present. It will involve the following:

1. Very liberal application of surface preservative to all accessible surface. Since depth of penetration is particularly important and since main stringers are almost by definition located in situations of perpetual dampness it may be preferable to use Polegel rather than KCN.
2. A carefully thought-out scheme for inserting diffusible preservatives. [See section 9.]

The existence of a large volume of internal rot or of a hollow can be detected by a combination of visual inspection, sounding exploratory drilling, and ultrasound scanning. Internal rot should be treated by insertion of diffusing preservative. A large hollow should be treated with foamed preservative. It will be necessary to somehow block off the open end of the hollow at the butt, which may not be easy, given that the butt end will be inserted in a slot in the bedrock. Given the importance of getting a good preservative loading, some leakage and environmental contamination will probably have to be accepted.

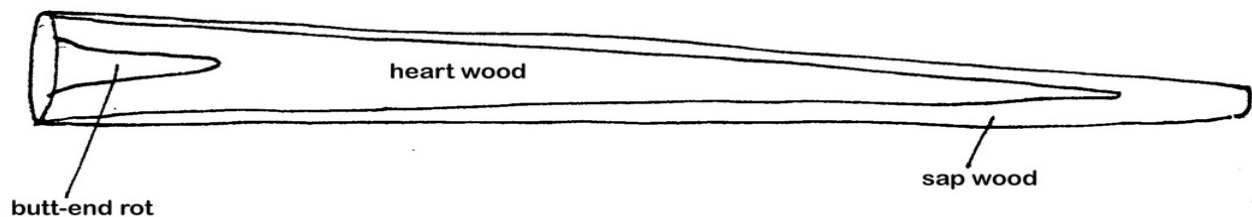


Fig. 31: Butt end rot in dam stringers

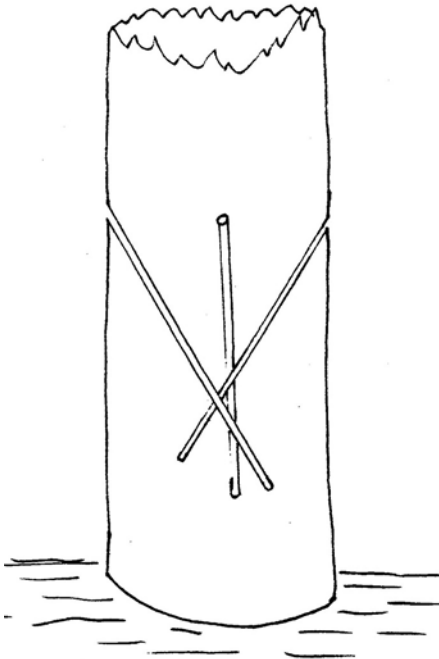


Fig. 32: Inserting diffusible preservative

After treating with foamed preservative consideration might be given to filling the cavities with rigid polyurethane foam (marketed in aerosol cans as "Space Invader"). This would strengthen the stringer, and provide an internal barrier against leakage inwards of diffusible preservatives circulating in the surrounding wood. A rigid foam fill would remove the necessity for periodic re-treatment with foamed preservative.

The other special problem situation with kauri dams is the lower ends of the rafters. These are generally sitting on bedrock, and are suffering end-grain rot in perpetually damp conditions. Pole bandaging in many cases is virtually impossible and is unlikely to be effective even if it were possible. The only thing that can probably be done to alleviate the situation is to bore holes diagonally into the timber near the lower end and fill with diffusible preservative, fig. 32.

[[ Add material on jubilee clamping ]]

## 3.00 TIMBERS

These are brief notes relating to the durability and use of the main species likely to be included in historical structures. More comprehensive references include New Zealand Timbers, exotic and indigenous, the complete guide: N.C.Clifton (GP Books, 1990) and Wood in Australia, Types, Properties and Uses: Keith R. Bootle (McGraw-Hill, 1983).

### 3.1 NEW ZEALAND KAURI (AGATHIS AUSTRALIS)

Widely used in all types of construction. Now classified as only moderately durable in ground contact (durability class 3), similar to rimu, matai and macrocarpa.

### 3.2 TOTARA (PODOCARPUS TOTARA, P. HALLII)

One of the most durable of New Zealand's timbers (durability class 1), totara was widely used for railway sleepers, fencing, foundation piles and poles as a result. It was also used in sheathing of buildings but its brittleness restricted its use in structural situations.

### 3.3 SILVER PINE, YELLOW SILVER PINE (LAGAROSTROBOS COLENSOI, LEPIDOTHAMNUS INTERMEDIUS)

The very durable heartwood (durability class 1) from these relatively small trees was widely used for railway sleepers, foundation piles, poles and fence posts.

### 3.4 KAWAKA, KAIKAWAKA (LIBOCEDRUS PLUMOSA, L BIDWILLII)

Originally used for much the same purposes as totara the lower durability of these species (durability class 3) later limited their use to less demanding uses such as exterior sheathing for buildings, roof shingles and boat planking. They were of even lower strength than totara and seldom used for structural components.

### 3.5 OTHER INDIGENOUS SOFTWOODS

Rimu (*Dacrydium cupressinum*), matai (*Prumnopitys taxifolia*) and miro (*Prumnopitys ferruginea*) were widely used in general construction. The heartwood of all of these species is only moderately durable (durability class 3), and where rimu or miro were used it is likely that non-durable sapwood would have been included. Kahikatea (*Dacrycarpus dacrydioides*), although having a reputation as being durable in wet conditions, is non-durable and is best known for its non-tainting sapwood, widely used in packaging such as butter boxes and particularly susceptible to attack by wood borers.

### 3.6 THE NEW ZEALAND BEECHES (*NOTHOFAGUS FUSCA*, *N. MENZIESII*, *N. SOLANDRI*, *N. TRUNCATA*)

Red beech (*N. fusca*) and hard beech (*N. truncata*) are durable hardwoods (durability class 2) and were widely used for railway sleepers, mining timbers, fencing and heavy construction. Silver beech (*N. menziesii*) usually has a lower proportion of heartwood which is less durable (durability class 3) and was occasionally used for sheathing but mainly in internal uses and furniture. Mountain beech (*N. solandri* var. *cliffortioides*) and black beech (*N. solandri* var. *solandri*) were used where they were locally common for much the same purposes as red and hard beech. Although their heartwood has the same durability rating as red and hard beech, they have a reputation for being less reliable.

### 3.7 PURIRI (*VITEX LUCENS*)

This very hard and durable timber was used for railway sleepers, piles, fencing and heavy construction such as bridges. Its irregular grain made it difficult to work and it frequently contained large holes left by the puriri moth larvae. Puriri was only available in the northern part of the country and in small quantities.

### 3.8 OTHER INDIGENOUS HARDWOODS

It was common for locally available species, not known for their durability, to be used in tramways, bridges, buildings and other structures that were expected to have a relatively short life e.g., until an area of bush had been logged. Hardwoods such as kamahi (*Weinmannia racemosa*), hinau (*Elaeocarpus dentatus*), rata (*Metrosideros umbellata*, *M. robusta*) mangeao (*Litsea calicaris*) and pukatea (*Laurelia noveau-zelandiae*) were often used in these structures and in the equipment needed to remove logs or other products from the forests.

### 3.9 DURABLE AUSTRALIAN HARDWOODS (REGAL HARDWOODS)

These very durable hardwoods (durability class 1) were imported for heavy construction wharves, bridges, transmission poles, crossarms and other uses where the requirements for high strength and very high durability could not be met by locally available species. They included the ironbarks (*Eucalyptus paniculata*, *E. crebra*, *E. siderophloia*), grey gums (*E. propinqua*, *E. punctata*), grey box (*E. hemiploia*), tallow wood (*E. microcorys*), white mahogany (*E. acmenioides*), red bloodwood (*E. gummifera*) and for marine piles, turpentine (*Syncarpia glomulifera*). While there was a requirement to label logs when they were felled, many consignments contained several species. This, and the fact that redundant timbers were often reused when structures were repaired, means that most structures will contain a mixture of species from the above group.

### 3.10 OTHER AUSTRALIAN HARDWOODS

Large quantities of general purpose Australian hardwoods were imported for structural uses where high strength was required but where the durability requirements were less critical e.g., railway sleepers, transmission crossarms, heavy construction. These were usually in durability class 2 or the upper end of class 3. They included jarrah (*E. marginata*), karri (*E. diversicolor*), blackbutt (*E. pilularis*), Sydney blue gum (*E. saligna*) and southern mahogany (*E. botryoides*). More recently these species, excluding jarrah and karri, have been imported as round transmission poles and marine piles with the sapwood preservative treated.

### 3.11 NEW ZEALAND GROWN EXOTIC SPECIES

Excluding preservative treated radiata pine there are other locally grown species with moderate durability that could be used to replace damaged or decayed timber in historic structures. All of these species are of limited availability so obtaining timber of the required quality and dimensions may be difficult or slow. The *Eucalyptus* species listed only grow well in the northern part of the country hence are probably not available in the south.

The cypresses, macrocarpa (*Cupressus macrocarpa*), Mexican cypress (*C. lusitanica*) and Lawson cypress (*Chamaecyparis lawsoniana*) are all in the same durability class as kauri and rimu. Macrocarpa and *lusitanica* heartwood is similar in color and texture to kauri and could be worth considering when repairing kauri structures.

Locally grown eucalyptus species with durability ratings of class 2-3 include white stringybark (*E. globoidea*), yellow stringybark (*E. muelleriana*), Sydney blue gum, southern mahogany and blackbutt. Sydney blue gum is probably the most widely planted of these but supplies are scattered and probably restricted to the North Island.

## 4.00 TRADITIONAL PRESERVATIVES

### 4.1 CREOSOTE

Creosote, patented in 1831, would easily be the most used timber preservative in New Zealand up until about 1950. The NZR began creosoting sleepers made of a variety of native timbers from 1886 onwards. Some sleepers creosoted prior to 1912 were still in service as late as the 1950s. The New Zealand Forest service showed quite early on that creosoted radiata fence posts would last 25 years in the ground.

A by-product of the coal gas industry, it is much less easily available than it was, but it is still imported and retailed in small packs. If it is known that a particular historic structure was originally treated with creosote and/or coal tar there is no reason why it should not continue to be coated in creosote, in the interests of historic authenticity. Stockholm tar [section 3.12], will make an excellent substitute for coal tar.

Creosote is an excellent fungicide and preservative. It has high fungal toxicity, it soaks into wood very readily, and it is insoluble in water and therefore does not leach out. Depth of penetration can be determined from direct observation without any need for indicator reagents. It confers little water repellency (but neither do most other preservatives).

It is hard to see why creosote has dropped so far out of favour in recent times. The usual reasons given are its unpleasant smell, its allegedly caustic effect on human skin, and the messy, dirty, sticky surface it imparts to wood for the first year or two after application. It is impossible to apply oil-based paint to creosoted wood. (There is no information about compatibility with acrylics)

It seems to be an accident of history that creosote went out of general use. In the 1950s, as quality native timbers began to run out, New Zealand was forced into a crash programme of finding ways of using the lower quality native timbers and radiata pine. A preservative was needed which was compatible with paint. This led to reliance on first pentachlorophenol (PCP) and later copper-chrome-arsenic (CCA) pressure treatments. Boron diffusion was developed for borer control. These seemed better on aesthetic or cosmetic grounds than messy, smelly old creosote which therefore fell into disfavour, even for fence posts and railway sleepers. By the time the environmental and health hazards of PCP (a polychlorinated hydrocarbon of the same ilk as DDT and dioxin) and CCA were appreciated, creosote was no longer being produced, as coal gas was giving way to Kapuni and then Maui natural gas. The NZR disposed of its stockpile of creosote in the 1970s. PCP was banned, and total reliance was placed on CCA. When pressure for more environmentally-friendly preservatives developed in the 1970s the FRI chose to investigate quaternary ammonium salts (or "quats") as a CCA substitute rather than re-investigate creosote. The quats were not up to the job, and so we are stuck with CCA, and arsenic and chromium levels must be slowly building up in New Zealand farmland as CCA-treated posts start to decay.



There is still a standard specification for creosote - NZSS 401, "Coal-tar creosote for the preservation of timber".

Creosote has a reputation as being unhealthy stuff to work with, but this is based on its smell and appearance more than anything else. According to a 1950 Forest Service publication (which possibly overstates the case!) "... creosote is one of the least hazardous substances used in industry, and ... the handling of creosoted timber is not a dangerous occupation". The NZFS quoted American and British works which dismissed fears that creosote caused serious skin inflammation or cancer.

As far as possible health hazards are concerned, the general obnoxiousness of creosote is the best thing it has going for it. It is self-policing, so to say. It smells and looks so bad that no-one takes any chances about getting it on or in their body, and if by mischance they do they will take immediate steps to get it off or out. Warm water and soap are all that are needed for external first aid. Vomiting (which will probably come naturally without any emetic other than the creosote itself) is the appropriate response to ingestion. Working with it in an unventilated enclosed space is unthinkable. To cut down on the fumes application of creosote is best done in cool weather. One disadvantage of creosote is that it considerably increases the flammability of recently treated timber.

Creosote is still being manufactured overseas as a bi-product of coke-making for the iron and steel industry. It is retailed in small packs in New Zealand and no doubt is available in 200 litre drums.

Small scale tests are underway on Tauranikau dam and on the subfloor framing of the author's 1940s untreated radiata house.

## 4.2 TAR

Coal tar was widely used to coat early timber structures, and remnants of tar coating will often be found on structures undergoing stabilisation. The tar was, however, being used more as a form of paint which kept water out of the wood, and it was never regarded as a penetrating fungicidal preservative.

There is a temptation to re-coat historic structures with coal tar in the belief that it has preservative properties, and in the interests of historic authenticity. This will not work, for three reasons:

- (a) coal tar has minimal fungicidal effect,
- (b) coal tar, a bi-product of town gasworks, is no longer readily available,
- (c) a fresh coat of coal tar will not adhere to old weathered damp wood any more than conventional paint will.

If something that looks and smells like tar is wanted, it is suggested that the structure be first treated with creosote, (which consists of fungicidal oils distilled from coal tar) and then with Stockholm tar. Stockholm tar is distilled from wood, and has modest fungicidal and water-repellent properties. It tends to penetrate and adhere to old timber more readily than coal tar, but less readily than does creosote. Tests in Sweden showed that it gives good protection against fungal rot, although it is not a good water repellent.

A small scale test is underway at Tauranikau.

### 4.3 OLD SUMP OIL

There are still people around who are adamant that old sump oil is as good a wood preservative as you will ever find. It was the preservative of choice for unpainted weatherboard sawmill houses on the West Coast until the 1950s. Oil from diesel engines is supposed to be better than oil from petrol engines. Tests in Sweden showed it to have a surprisingly high fungicidal effect, although it conferred little water repellency. The old New Zealand Forest Service recommended old sump oil as a carrier for copper naphthenate. A small scale test is underway at Tauranikau.

### 4.4 RED LEAD

Red lead oxide in boiled linseed oil was another traditional surface coating for both timber and steel structures. It has good fungicidal and insecticidal properties, although of course it is now regarded as hazardous to health and to the environment. Where it is still present it should be left. If it is still sticking to the wood after waterblasting then it isn't doing any harm, and it may be doing some good, and it will not impede the entry of modern preservative.

### 4.5 PENTACHLOROPHENOL

## 5.00 SOURCES OF SUPPLY

This Appendix lists the various materials and services needed for historic timber preservation in more or less the same order as they are mentioned in the main text. A supplier for each item is given. Contact details about the suppliers are in a second list. Often this is the wholesaler or manufacturer, who should be contacted to find the most convenient local stockist.

### 5.1 MATERIALS AND SERVICES

### 5.2 SUPPLIERS

#### **Preliminaries**

- Sodium sulphide
- Increment borers
- Identification of wood
- Surface preservatives
- Copper naphthenate concentrate
- Copper naphthenate emulsion
- Creosote (ordinary)
- Creosote emulsion

#### **Internal preservatives etc.**

- Boron foam
- Boron paste
- Boron rods
- Polyurethane foam, 750 ml aerosol cans
- Plugs, plastic, for closing diffusible insertion holes

#### **Groundline and waterline preservatives**

- Bandages
- Bituminous mastic
- Petrolatum tape
- Geotextile
- Plastic membrane for in-water piles
- Marine-grade densotape
- Concrete grout for casting round in-water piles
- Polegel cartridges
- Polegel, 20 l pails

### **Special situations**

Butynol  
Rust-inhibiting grease  
Blue 7  
Fish-oil  
Lead sheeting  
Fish oil  
Boron powder

### **Other treatments**

Polyvinyl butyral consolidant solution  
Polyvinyl butyral resin  
Acetone  
Epoxy consolidant Ever-dure  
Water repellents  
Shrink tape  
Permethrin

### **Colour standard chart.**

Assays for copper-based preservatives  
Assays for boron-based preservatives  
spot test for copper  
Spot tests for boron  
Spot test for boron and copper

## **COPPER NAPHTHENATE FOOTNOTES**

- 6 The tests at Waikino have shown that CNE is reasonably cheap on a per-square-metre basis.
- 7 Assays of bridges treated several years ago in Waioeka gorge indicate that CNE provides surface protection equal to that of H3 radiata for at least 8 years. Similar assays of Busan-treated structures have given less conclusive (though not necessarily unsatisfactory) results.
- 8 As a copper based preservative the effectiveness of treatment is very easily tested by assay, at about \$15 a sample. Busan assays, by contrast cost at least \$120 each. There is a simple spot test for copper, but none for Busan.

# GLOSSARY

An asterisk indicates that the term, although used in this manual, is not in general usage. Preferred terms are explained. Alternative terms and synonyms are listed, with a cross-reference to the preferred term.

abutment:	The end of a bridge, where the bridge, or its land-span, rests on the ground. See figures 1-4.
Acro-prop:	A galvanised tube, generally about 3 m long with length adjustable by means of a threaded end-piece, used for supporting scaffolding, form work during construction etc.
assay:	Laboratory determination of the amount or proportion of a particular substance in a sample.
baluster:	Vertical post supporting a handrail. See fig. 2.
bay:	A bridge truss is made up of several bays, each bay consisting of the rectangle lying between two sets of truss rods. See fig. 1.
beam, floor:	On NZR Howe truss bridges, transoms were called floor beams.
beam, main:	The longitudinal beams stretching from pier to pier and carrying the decking (on a road bridge) or sleepers (on a rail bridge, where they are also called rail beams), figures . 3, & 22. When the beams rest on transoms (as in truss and suspension bridges) they are referred to as stringers.
beam, rail:	See beam, main
beam, straining:	A beam underneath a bridge main beam and between opposing understruts. See fig. 3b.
block, "A":	A compression block set into the top chord of a Howe truss to transfer thrust from the strut to the several fitches of the chord. See figures 1 & 21.
block, packing:	A piece of timber filling in a space between two other timbers. See packing.
block, reaction:	Apparently another name for an "A" block.
block, saddle:	The block which transfers stresses between the truss rod, the top chord, and the truss brace of a Howe truss. See figures 1 & 21.
block, thrust:	Equivalent to an "A" block, but set into the bottom chord. See figures 1 & 27.
bolt, strap:	A bolt with a flattened end, used for example to fasten a cap to a pile top.
boron:	Fifth element in the periodic table, hence has a very small atom which diffuses readily. Used as a fungicide insecticide and fire retardant in timber, generally as mixtures containing disodium octoborate, which breaks down with water to form boric acid.

brace (or bracing):	A secondary element of a structure which stiffens the primary elements.
brace, beam*:	A diagonal brace between a pier and a main beam which provides support to the beam. See fig. 3.
brace, longitudinal:	A horizontal beam running between adjacent piers to stiffen the piers. See fig. 3.
brace, sway:	
brace, transverse:	A length of timber or (on NZR bridges especially) an old railway line which braces the piles or studs of a pier. Both horizontal and diagonal braces are needed. See fig. 3.
brace, truss:	The external brace connected to a transom outrigger to provide lateral stiffening to the truss. Also known as a wind brace. See fig. 2 & 21.
brace, wind:	a horizontal diagonal brace under the decking or over the carriageway to prevent a bridge span swaying in the wind.
Busan:	Brand name for a range of fungicides made in the US by Buckman Laboratories, based on the fungicide TCMTB.
Busan 30L:	A timber preservative in which the active fungicidal ingredient is TCMTB at 30% concentration. It is water-miscible.
cap, pile:	A horizontal timber which sits across the tops of piles or studs and supports the corbels. See fig. 22.
CCA:	Copper-chromium-arsenic, the preservative used in pressure treatment of radiata pine for fenceposts etc. Often referred to as "tanalising".
CD50:	Copper-8-quinolinolate. An oil dressing for cedar weatherboards etc., containing copper quinolate as a preservative, sold by Churton Distributors of Auckland.
checks, checking:	Longitudinal cracks and fissures opening up on timber surfaces in response to weathering.
chord:	The main horizontal longitudinal components at the top and bottom of a truss. The top chord is under compression and is generally made up of several fitches. The bottom chord is under tension and is often made of two steel plates. See fig. 1.
CNE*:	Abbreviation for copper naphthenate emulsion. An emulsified fungicide formulation designed to improve sustained, deep penetration into wood.
CNL*:	Copper naphthenate liquid. A wood preservative containing copper naphthenate in a liquid formulation.

consolidant:	A dilute solution of a synthetic resin which soaks into timber then sets hard, thus strengthening the timber as well as reducing its permeability to moisture.
copper naphthenate:	A fungicide. See CNL and CNE.
copper quinolate:	A fungicide, the active ingredient in CD50.
corbel:	A timber on top of a pier which spreads the support provided by the pier to the main bridge beams. See figures 20 & 21.
counter:	See strut, counter.
creosote:	A fungicidal wood preservative distilled from coal tar.
CSIRO:	Commonwealth Scientific & Industrial Research Organisation, Australia.
Densotape:	A synthetic fibre tape liberally coated with petrolatum and corrosion inhibitor. Moulds to fit odd shapes, hardens slowly on exposure. Used within DOC principally to wrap turnbuckles, shackles etc. on suspension footbridges.
DMAD:	Dimethylamide modified fatty acids. A powerful solvent which helps preservative penetrate into wood.
extractives:	Substances deposited in the cells of heartwood such as gums, resins, tannins etc. Some are natural fungicides and confer durability. Called extractives because they are easily extracted with solvents.
falsework:	Temporary framework to hold up a bridge while it is under repair.
fibre saturation point:	(FSP) The moisture content at which the wood cell walls become saturated. Above this moisture content water accumulates in cell lumens (space or void in the cells).
fishplate:	Any steel strap bolted between two components to hold them in a alignment (especially the plates used to connect consecutive rails in a railway). See fig. 12.
fitch:	A long timber much deeper than it is wide. Chords and struts on a Howe truss are made up of several fitches separated by spacers. See figures 1 & 2.
FRI:	The former Forest Research Institute of the New Zealand Forest Service. Now called Forest Research (FR).
fungicide:	A chemical which kills fungi. More particularly in this manual, one which kills rot fungi. Some fungicides are much more efficient than others, but a good fungicide does not necessarily make a good wood preservative, and a good preservative does not necessarily contain the most efficient fungicide.

grain, side*:	Timber surfaces which are parallel to the grain are here referred to as side-grain surfaces.
grainend:	The grain exposed in the transverse section of timber.
hardwood:	Timber from a broadleaved tree, e.g., eucalypt, native beech or oak. The timber is not necessarily hard (balsa is a hardwood). Hardwoods are characterised micro-scopically by large vessels which provide good longitudinal permeability for fungicide. (see also softwood)
Howe truss:	A truss for supporting bridge spans specially suited to wooden construction. It is characterised by diagonal struts under compression and vertical tie rods under tension. See fig. 1.
H1:	Radiata pine treated by the boron diffusion process to protect it against boron attack, for use in situations protected from the weather. (Specification for the treatment of timber which is used out of contact with the ground and continuously protected from the weather, primarily against attack by wood boring beetles.)
H3:	Radiata pine treated with sufficient CCA to protect it from rot in situations exposed to weather but not to ground contact. (Specification for the treatment of timber which is used out of contact with the ground but may be exposed to the weather.)
H4:	Radiata pine treated with sufficient CCA to protect it from rot for 20 years or more in contact with the ground. (Specification for the treatment of timber which is used in fresh water or in contact with the ground or in situations favourable to decay. Expected life in normal ground contact, more than 25 years.)
H5:	Radiata pine treated with sufficient CCA to protect it from rot for 50 years or more in ground contact - used for house piles etc. (Specification for the treatment of timber which is used in contact with the ground in critical structural situations or where an extremely high decay hazard exists. Expected life in normal ground contact, 50 years.)
joggle pin:	A heavy steel pin inserted into a hole drilled between two parallel timbers, and designed to prevent longitudinal movement of one timber relative to the other. See fig. 27. A joggle block is a wooden block serving the same purpose.



join, butt:	A join in which the endgrain surfaces of two timbers are in contact.
join, lap:	A join in which timbers are overlapped, or in which the timbers lie alongside the other, so that along-grain surfaces are in contact.
join, scarf:	A join mostly used during repairs, see fig. 10. They are also widely used in new construction and come in various shapes and sizes, e.g., half scarf, angle scarf.
Koppers:	Koppers Arch Wood Protection, a manufacturer of timber preservatives.
lift:	A trestle is said to be made up of several lifts when the vertical timbers used are not sufficient to reach the total height needed, so that vertical timbers have to be joined end to end via a spreader.
LOSP:	Light Organic Solvent Preservative (timber). A preservative such as copper naphthenate carried in white spirits or turps.
Metalex:	Brand name for a 4% copper naphthenate solution widely used in New Zealand .
meths:	Methylated spirits, mostly made up of ethyl alcohol.
moisture content:	(MC) The amount of moisture in wood measured as a percentage of oven-dry weight. Can range in outdoor conditions from 10% to over 100%.
MoW:	The former Ministry of Works (earlier the Public Works Department).
NZR:	New Zealand Railways (pre-corporatisation).
outrigger, deck*:	A deckplank extending out beyond the deck to provide support for a baluster brace. See fig. 2.
outrigger, transom:	Extension of a transom beyond the deck to provide support for a truss brace. See fig. 2.
Osmose:	Timber protection company now controlling the former FERNZ Timber Protection and Protim companies.
packing:	Any timber in addition to the normal structural elements used to achieve the correct spacing of those elements.
pier:	The supporting structure for the spans of a multi-span bridge, made up of piles etc.
pile:	A long timber, generally roundwood, driven (by striking the top end with a heavy weight) into the ground or into riverbed. See fig. 3. Compare with pole and post pile, brace: Synonym for raker pile.

pile, cut-water:	A pile driven into the riverbed upstream of a bridge pier to protect the pier against flood-borne logs etc. See fig. 3.
pile, raker:	A pile driven at an angle to provide support and bracing to a bridge pier. See fig. 3.
Pole:	A large vertical timber held erect by being set (not driven) into the ground. Compare with pile and post.
Polegel*:	Busan pole preservative gel, a diffusible formulation with 15% TCMTB.
post:	A shorter vertical timber set into the ground, to support a fence or sign etc. Compare with pile and pole.
psi:	Pounds per square inch.
radial:	In a transverse section of timber, any line running from the centre of the original log towards the bark. Compare with 'tangential'. See fig. 15.
regal eucalypts:	A group of Australian red coloured eucalypt species known for their hardness and durability. Includes, ironbark, grey gum, tallow-wood, red bloodwood etc. More generally but less precisely referred to as Australian hardwoods. Jarrah is not included here as it is only class 2 durability although jarrah is a term often used to describe red coloured eucalypt wood.
repellent, water:	Substances such as waxes and resins to which water molecules are not attracted.
rod, tie:	A long rod which tensions a structure either by a turnbuckle in the middle or a thread and nut at one end. A truss rod is a special form of tie rod. A cross tie (or wind brace) is a horizontal transverse tie rod bracing a pair of trusses, generally under the decking.
rod, truss:	The large vertical tie rods in a Howe truss.
rot, brown:	The most common rot in the structures dealt with in this manual. Characterised by soft patches brown in colour and with a fissured cuboidal texture. Caused by fungi which consume (white) cellulose fibres but not (brown) lignin.
rot, butt-end*:	Internal rot generally resulting a large central cavity at what was originally the lower end of the growing tree. Often develops in the live, standing tree, and not always removed when long timbers were needed. Regal eucalypts are prone to butt-end rot. See fig. 20.
rot, centre:	See pipe rot.
rot, end grain:	rot proceeding into a timber from the end grain.

rot, internal:	Any rot which is not on the surface, includes pipe rot, centre rot, and butt-end rot. See figures 8 & 20.
rot, groundline*:	Rot occurring where a post enters the ground. Also called collar rot. See fig. 20.
rot, gutter*:	Rot forming a channel along the upper surface of a bridge beam or stringer, caused by water entering spike holes, See figures 24 & 25.
rot, pipe:	Rot forming along the pith core of a eucalypt, often while the tree is still alive. When it progresses into the surrounding heart wood it becomes centre rot. See figures 16 & 20.
rot, soft:	Rot, characterised by softening or corkiness of wood, caused by microfungi resident in wood cell walls rather than lumens, and therefore hard to treat. Not easily visible, but can lead to timbers suddenly snapping the way a carrot can be snapped. Regal eucalypts are prone to soft rot, especially at the groundline.
rot, surface:	Rot happening at the surface, particularly on side-grain surfaces, where it is easy to treat.
rot, white:	Rot which results in whitish fibrous soft patches. Caused by fungi which consume mainly lignin but leave some cellulose.
rot, top-end*:	Rot occurring at the unprotected top ends of poles, posts etc., where rain has easy access to end grain.
shim:	A thin spacer of metal or wood.
sill:	A horizontal timber resting on the ground or on a concrete footing, providing support to timber super-structure. See figures 1 & 3.
sodium hypochlorite:	The active ingredient in household bleach, toxic to surface mould fungi. Also very toxic to freshwater fish, therefore not to be used near waterways.
softwood:	The wood of pines and related trees, characterised by large numbers of tracheid cells which may provide good longitudinal permeability for preservative. The timber is not necessarily soft. Totara and kauri are softwoods (see also hardwood).
span:	All the structure between two piers. A land span has one span resting on a pier and the other end on an abutment. See fig. 4.
spreader:	Usually a block or short beam which maintains the correct separation between two main beams. Also a horizontal timber in a trestle which

	connects the tops of a lower lift of piles or studs and supports the bases of an upper lift. See fig. 3.
Stockholm tar:	Tar derived from the destructive distillation of wood, sold mostly in this country for veterinary use. Formerly used for preserving hemp rope etc. in marine situations.
stringer:	Any horizontal timber running longitudinally, e.g., the beams laid between transoms supporting the deck on a suspension bridge.
strut:	Another term for a brace. In particular the longitudinal diagonal compression braces of a Howe truss. These all, except for counter struts, slope up towards the middle of the span. Ordinary struts (i.e., excluding king and queen struts) are called centre struts.
strut, counter:	A strut which provides additional strengthening to the middle bay(s) of a truss. Made of a single flitch which passes between the two flitches of a centre strut.
strut, king:	The sloping end post of a truss, which transfers most of the compression in the top chord to the king thrust block. The king struts are made of heavier timber than the other parts of the truss. See fig. 1.
strut, queen:	The strut next to the king strut, and made of somewhat lighter timber. See fig. 1.
strut, under:	A diagonal longitudinal strut providing support to the quarter-length point of a beam from a pier. See fig. 3.
stud:	A vertical timber in a supporting role, other than timbers driven into the ground, which are piles.
stud, raker:	A stud performing similar function to a raker pile. See fig. 3.
tangential:	In a transverse section of a log the tangential direction is that perpendicular to a radius, i.e., parallel to the growth ring. See fig. 15.
TCMTB:	2-(thiocyanomethylthio) benzothiazole, an organic fungicide effective in particular against mould, sapstain and soft rot.
tie, cross:	See rod, tie.
Tim-bor:	A powder formulation of boron salts used in commercial diffusion treatment of radiata.
TPC NZ :	New Zealand Timber Protection Council Inc. Sets standard for commercial treatments.
trestle:	A pier made up of piles and/or studs, together with caps, sills etc.

transom:	A transverse timber in any structure (c.f. stringer). More particularly the transverse timber supported by piers or suspension bridge hangers and supporting the deck beams, railbeams or stringers. On NZR bridges they were called floor beams. See fig. 2.
truss rod:	A vertical metal tie rod, the feature which distinguishes Howe trusses from other trusses.
turps:	mineral turpentine, as used in oil-based paints.
viaduct:	A high bridge built to span a valley, rather than just span a river.
waling:	Horizontal plank-like timbers on a bridge which provide bracing and/or protect piers against the impact of flood-borne debris. See fig. 3.
wheel guard:	Timber at the side of a bridge deck to prevent vehicles hitting the truss. See fig. 2.
wood, dozy:	Wood which has just started to rot, so that its appearance has hardly changed although the wood is significantly weakened and soft.
wood, heart:	The inner part of a log, much less permeable and generally more durable than sap.
wood, sap:	The younger, live wood on the outside of a tree. See heart wood.