In-service wood preservative test on the Howe truss railway bridge, Waikino

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Abstract

Some of the major components of a Howe truss bridge, built from durable Australian hardwoods, were treated with preservatives applied to the surface and inserted into holes bored into the components. The preservatives included two copper naphthenate formulations, two formulations based on 2-(thiocyanomethylthio) benzothiazeole (TCMTB), two boron-based products and an oxine-copper formulation. The application methods, preservative characteristics and preservative costs are described. Adequate surface retentions were achieved with all chemicals although two coats were required for the oxine-copper and one of the copper naphthenate formulations. Although there appeared to be significant differences in retentions and costs the relative benefit of the products will only be determined by a long-term monitoring programme.

1. Introduction

Wooden bridges incorporating Howe trusses as their main structural component were a common feature on roads and railways throughout New Zealand. Most have since been replaced by modern reinforced concrete structures as routes changed and traffic loadings increased, but a few have been retained as structures of historical interest. Durable Australian hardwoods, mainly Eucalyptus species, were the preferred timbers for these structures and gave good service for 50 years or more. Continuing gradual deterioration of the components means that a programme of component replacement or protective maintenance is necessary if they are to be retained for any significant time.

Two large hardwood bridges in the Waioeka gorge have been previously treated with CN Emulsion (a product containing copper naphthenate), the Manganuku bridge in 1991 and the Tauranga bridge in 1996. Chemical analyses of surface wood samples in 1999 showed that the outer two millimetres of the treated wood on both bridges still contained more than 0.1% copper (the minimum requirement for wood treated with copper naphthenate exposed to the weather but not in ground contact). Details of the amount of preservative applied are sketchy but the analyses indicate that the preservative was relatively persistent and that it had not penetrated far into sound wood. The most exposed wood on the Tauranga bridge and all of the treated wood on the Manganuku bridge has returned to a grey weathered colour indicating that weathering is continuing, but there were no untreated areas on the components which could be used to directly compare deterioration rates. While it is difficult to gauge whether the treatment has been beneficial, the continued presence of reasonable retentions of copper indicate that decay fungi activity on the surface is probably being inhibited.

A test of remedial preservative treatments was established on the rail bridge to the east of the Waikino railway station on the Goldfields Rail Inc. line between Waihi and Waikino. The bridge, over the Waitekauri stream, was originally constructed in the early 1900s and was part of the main line between Paeroa and Waihi until the 1960s. During that period it was regularly inspected and maintained, but maintenance lapsed and little more was done until the Goldfields Railway established a tourist venture on the line in the 1980s. The loading capacity of the bridge was downgraded after the main line closed, and a number of the existing components contain significant decay.

This test was established to determine the efficacy of different preservative chemicals, the practicality of their application, and associated costs. Only a small number of preservatives were tested, on a small number of components. This report covers the initial stages of the tests, i.e. preservative application and retention of surface-applied preservatives. Further information is required on deterioration and preservative retention after a prolonged exposure period, before the benefits of the preservative treatments can be evaluated.

2. Materials and methods

The bridge was inspected and a list of components suitable for treatment was compiled (Figures 1 & 2). The chemicals chosen were all readily available and had a reputation as being suitable for remedial treatment of wood in service or had been used previously to treat wooden structures of historical interest.They were separated into two treatment groups, brush-on surface application and inserted into holes bored in the wood. The testing of pole bandage systems was considered, but there were no components on the bridge suitable for treatment using bandages and the bandages available in New Zealand are only supplied to specialised contractors for use with Busan Pole Gel.

Busan 30L is supplied as a 30% 2-(thiocyanomethylthio) benzothiazole (TCMTB) liquid concentrate and forms an emulsion with water. Its main use is as an anti-sapstain chemical at solution concentrations of approximately 0.3%. It is classified as a poison of relatively low toxicity (LD50 oral toxicity (rats) 1200 mg/kg) although it is a skin irritant which can cause allergic reactions in some people. Aerosols from spraying are toxic and must not be inhaled. A solution strength of 10% is recommended for remedial treatment of wood.

Busan Pole Preservation Gel is supplied as a ready-to-use soft gel containing 15% TCMTB with 15% Busperse 47, a wood penetrant. Developed mainly for use with bandage application systems, it can also be injected into holes bored in components and as a surface application. The toxicity ratings and handling precautions are similar to those given for Busan 30L.

Metallex (green) is a 34% solution of copper naphthenate in mineral turpentine and dilution 1:3 with an organic solvent such as mineral turpentine, diesel or oil is recommended. Copper naphthenate is classified of low toxicity (LD_{50} oral toxicity (rats) >6000 mg/kg) and may cause temporary irritation in contact with the skin. It has been used commercially for pressure treatment of wood as well as in remedial treatment formulations.

CN Timber Protective Emulsion is a ready-to-use soft paste containing 15% copper naphthenate in a mineral oil and water emulsion. The toxicity ratings and handling precautions are similar to those given for Metallex. CN Emulsion was formulated for remedial treatment of wood including surface application, bandage application and injection.

Boracol 400RH is a viscous liquid containing 40% di-sodium octoborate tetrahydrate and 10% benzalkonium chloride, a quaternary ammonium compound. It can be used as formulated or diluted with water and has a low toxicity classification (LD50 oral toxicity >6216 mg/kg). The Ultrawood water-repellent used is a non-toxic, hydrocarbon-based emulsion used in commercial pressure treatment with waterborne preservatives. Boron-based products have been widely used for commercial and remedial treatments. The benzalkonium chloride component has fungicidal properties and has been used commercially in preservative treatments but is a minor part of this formulation.

Impel rods are 12 mm diameter fused boron glass rods, approximately 100 mm long containing 25 g di-sodium octaborate which breaks down in contact with water to form approximately 35 g boric acid. They are used extensively for remedial treatment of wood and are of low toxicity (LD50 oral toxicity 1760 mg/kg).

CD50 is a ready-to-use liquid formulation of approximately 0.28% copper-8-quinolinolate (oxine copper) in mineral oil. Oxine copper is used commercially in oil-based mixtures for pressure treatment of timber in the United States, mainly for components in contact with food and away from ground contact. In New Zealand it has been used for sapstain control in water-based solutions. Oxine copper has low toxicity (LD50 oral toxicity 4000 mg/kg)

Other preservatives which have been used for remedial treatments and are available in New Zealand were not included because the active ingredient in another formulation was already included in the test. These included Cuprinol (copper naphthenate), Diffusol (thickened boron) and Polesaver rods (fused boron). The small number of components also limited the number of different preservatives that could be tested. Those excluded because they were likely to be less effective were: Enseal Clear and Metallex Clear (zinc naphthenate) and Woodlife II (3-ido-2-propynyl butyl carbamate or IPBC). Creosote was also excluded because supplies in New Zealand are limited and it contains relatively toxic compounds. There are other preservatives in use overseas which were not tested because they contain relatively toxic ingredients, e.g. Blue 7 (copper-fluoride-boron paste), Basilit BFB (copper-fluoride-phenol liquid), Osmosar (fluoride-chrome-arsenic-phenol liquid), DFCK paste (dinitrophenol-copper-chrome-fluoride) and Permapruf T (tributyltin oxide and quaternary-ammonium-paste).

2.1 SURFACE TREATMENTS

Only the parts of the bridge which were easily accessible from the deck were considered for preservative testing. These included the lower sections of the 45° angled struts, the upper surface of the transoms, and the compression blocks at the base of the 45° struts. Treatment of the semi-vertical sway braces was initially planned, but difficulties with safe access and risk of chemical spillage into the river resulted in only one brace being partly treated.

The components were grouped by size and shape, i.e. large (king and queen) struts, small double and single struts, compression blocks and transoms. These were allocated to treatments so that there was at least one of each component type in each treatment group (Figure 3).

The bridge was cleaned with a standard 25 000 kPa water-blaster before any preservatives were applied. Only those surfaces which were easily accessible from the deck of the bridge were cleaned, hence some algae and lichen remained on the outer surfaces of the trusses after cleaning.

Before coatings were applied, a tarpaulin was suspended below the area of the bridge being treated, to prevent splashing or spillage of chemical into the river. Planks were tied to the diagonal steel braces spanning the area between the transoms to provide access to the truss components (Figure 4). The 45° sloping struts were coated on all four surfaces for the lower 2.5 m of their length. The upper sections of the struts were left uncoated to act as untreated controls and to give a direct comparison between treated and untreated wood. The upper surfaces of the transoms and all exposed surfaces of the compression blocks were coated, generally with the same preservative as was used on the 45° component in contact with them.

The surface-applied preservatives were all brushed on using standard paint brushes. The irregular surfaces of some components made it difficult to get an even spread of the more viscous chemicals, but they were applied generously and brushed out to give a relatively even coating. On deeply fissured surface the CN emulsion and Busan Pole Gel filled many of the cracks and fissures. Where algae or lichen remained after water-blasting, coatings were applied without removing the growth.

Where chemicals required mixing, the approximate amount required for each day's work was mixed immediately before application. The amounts of chemicals used were measured by weighing containers before and after each day's treatments. No separate measurements were taken of chemical absorbed by brushes or lost by drippage.

After the treatments were completed, the bridge was left for six days so that the preservatives could diffuse into the wood. Two samples, approximately 0-2 mm deep and 2-4 mm deep, were taken for chemical analysis from each of three or four sample points for each preservative. The sample points were on two components and included at least one 45°, one vertical, and one horizontal surface.

2.2 INSERTED PRESERVATIVES

The ends of stringers were used for tests of inserted preservatives. Three horizontal, 14 mm diameter holes, approximately 160 mm deep, were bored in the exposed side, 180 mm from the end of the stringer. The top and bottom holes were 50-70 mm from the upper and lower edges and the third hole was approximately in the centre of the stringer. Two sets of holes were bored for each preservative (Figures 3 and 8).

Shavings from the holes were collected in sealed plastic bags and their characteristics were noted as the holes were bored. They were later weighed, oven dried at 104° C and reweighed, to determine the approximate moisture content of the stringers in the vicinity of the treatments.

The preservative was inserted into the holes and the holes sealed with removable tapered plastic plugs, tapped in with a hammer. The copper naphthenate emulsion and the Busan Pole Gel were in cartridge tubes and were injected using a caulking gun until each hole was full. A single rod, approximately 100 mm long and 12 mm diameter was inserted into each hole in the stringers treated with Impel rods.

3. Results and discussion

3.1 PRESERVATIVE CHARACTERISTICS

Busan 30L (B30L)

Milky liquid mixed with water, 2 volumes of water to one of Busan 30L. Brushed on easily, tended to run and drip off the brush and surfaces that were not horizontal. Difficult to see where it had been applied within a few minutes. Pooled in crevices in the wood. Seemed dry but a heavy shower of rain produced noticeable milky runoff. A significant amount of spillage and splashing. Persistent penetrating smell.

Busan Pole Gel (BPG)

Thick cream-coloured emulsion, similar to soft margarine, brushed on directly from the container. Applied thickly and then brushed out into crevices. Spread reasonably easily but did not go into crevices well, lots of patches of thick preservative and an uneven coverage resulted. Remained on the surface for many hours, particularly where it was reasonably thick. Seemed to soak into the surface slowly in bright sunlight, but there was significant washoff during a shower of rain, shortly after application. Timber changed to a dark colour, similar to that treated with oil based preservatives, where the Pole Gel had soaked in. No problem with spillage, persistent penetrating smell.

The Busan Pole Gel in cartridges was more liquid than the same preservative in the 20 litre container, used for surface treatments. The reason for this is not known, but some of the preservative leaked back out of the holes bored in the stringers and out of the end of one stringer which contained large internal shakes.

Boracol + Ultrawood water-repellent (BORU)

Viscous, clear, sticky liquid. Ultrawood water-repellent is a milky liquid, similar in viscosity to water. A measured volume of Boracol was placed in a container and 10% of water-repellent (by volume) was added. The water-repellent mixed well with the Boracol but the mixture was rather sticky and, when applied with brush, spread with difficulty. It was applied thickly and then brushed out, but was difficult to see where it had been applied after a few minutes, particularly if the surface was damp. Penetrated into crevices better than the thick emulsions and spread on damp surfaces more readily than on very dry surfaces. In areas where orange algae had not been removed by water blasting, brushing with the chemical tended to remove patches of algae. No significant problem with spillage or splashing.

CD50

A dark oily liquid which appeared to contain some crystals in suspension. A small amount settled out in the bottom of the container and needed frequent stirring to keep it in suspension. Brushed on easily, directly from the container. More viscous than Busan 30L and copper naphthenate in diesel, hence there was less splashing and drippage from brushes or treated components. This was probably the easiest of the preservatives to apply. It seemed to spread and penetrate well, even in deeply fissured surfaces, and darkened the timber slightly. Spillage was relatively minor, but sufficient that care in application was needed.

Metallex (green) + diesel (CNO)

Three litres of light diesel fuel was added to one litre of Metallex green (34% copper naphthenate) concentrate. The dark green mixture was of very low viscosity, tended to splash or drip from brushes and non-horizontal surfaces. It spread easily, seemed to penetrate well and went into crevices easily, leaving the surface a dark colour. In damp areas the copper naphthenate seemed to come out of solution and form small bright green patches on the surface. Significant splashing and drippage occurred during application, but the preservative did not appear to be affected by rain immediately after application.

CN Emulsion (KCNE)

Thick bright green emulsion similar in texture to soft margarine. Brushed on straight from the container. Applied thickly and then brushed out over a much wider area. Spread reasonably easily but was difficult to get into fissures and therefore coverage was uneven. Where it was evenly spread it disappeared after an hour or two of bright sunshine, leaving the timber dark in colour similar to freshly oiled timber. Otherwise, where the preservative was thick on the surface or in fissures the bright green colour remained plainly visible for several days. When applied to damp surfaces the green colour was retained for a longer period. No problem with spillage.

CN emulsion from a 20 litre pail was put into caulking cartridges using a spatula. It was then injected easily into the holes in the stringers.

Impel Rods

Solid, opaque glass colour, 12 mm diameter x 110 mm long, easy to handle and use but fragile.

3.2 SURFACE TREATMENTS

Water-blasting removed almost all of the orange algae and lichen plus most of the debris and vegetation which had collected in the fissures. There was still a thin envelope of degraded wood on the surface of most components and areas of decayed wood on those surfaces with many deep fissures and more severe degradation. Cleaning with higher pressure would have taken the surface back to sound wood or removed most of the surface decay, but this is likely to have also reduced surface absorbency and uptake of preservative.

Preservatives were applied over four days, while the surfaces were generally dry. Upper surfaces were damp in the early morning and after brief rain showers in the middle of the first and second days which meant that the oil-based preservatives could not be applied until the surfaces dried out. The rain showers caused some loss of the Busan 30L and Busan Pole Gel treatments which had been applied immediately before it, but had no other obvious effect.

The application rates for the preservatives varied considerably, less preservative being used on the smoother surfaces than those which were deeply fissured. In all cases it was the upper surfaces which were most severely fissured, both the vertical faces and undersides of the components being relatively smooth. Application rates for the components treated are in Table 2 and Table 2a. The amount of active ingredient applied is shown in the last column of these Tables. This was based on chemical analyses of samples of the preservatives and shows elemental copper for the three formulations based on copper naphthenate and for CD50, boric acid for the Boracol mixture and TCMTB for the two Busan formulations.

The recommended application rate for CN Emulsion is a 3-6 mm thick coating over the surface or approximately 2.8-5.7 kg/m^2. The average application rate achieved was only 0.4 kg/m^2, but application of a much thicker coating would have been more difficult. With penetration likely to be limited to the outer few millimetres of wood, the amount applied may still be sufficient to prevent decay.

The Boracol application rate was several times the recommended rate. The very rough nature of the surface meant that it was impracticable to reduce the application rate to the level recommended. This suggests that a lower strength Boracol solution such as Boracol 200RH or even Boracol 100 would be suitable and the lower viscosity of these formulations would make application easier.

There were no recommended application rates for the Busan 30L or for the Busan Pole Gel because the products were not originally intended for this type of use. Busan Pole Gel is normally used for bandage and injected remedial treatment of poles and Busan 30L is normally used as an anti-sapstain formulation. The supplier suggested that Busan Pole Gel could be diluted with up to an equal amount of water for surface application. This was not done, mainly because the resulting liquid would have been very similar to Busan 30L. The Busan Pole Gel was applied at a similar rate to that for the CN Emulsion. Because Busan Pole Gel has 15% active ingredient compared to only 10% for the Busan 30L, the level of active ingredient retained on the surface was much higher for the former.

The Metallex in diesel was applied at a similar rate to the Busan 30L and the CD50. Chemical analyses a week later indicated that the amount of copper naphthenate retained was insufficient to prevent decay in most samples and a second coat was applied nine weeks later. This could have been done earlier, but an interval of several days between coats is probably necessary to allow the diesel to evaporate or to soak into the wood. Otherwise, preservative uptake when the second coat was applied could have been much lower than achieved with the first coat.

For CD50 an application rate of 3-5 m^2/litre is expected on shingles and shakes or 5-7 m^2/litre on old timber compared to approximately 2 m^2/litre achieved in this trial.A second application of CD50 is recommended after four weeks or so and a third optional coat within the next 8-12 months. A second coat was applied after nine weeks. Application of a third coat within the first twelve months was not considered because of the extra cost and the relatively high application rates for the first two coats.

After one week the appearance of the bridge had changed, with all of the lichen and algae growth which had been painted with preservative a bleached colour. The Busan Pole Gel and CN Emulsion had almost all diffused into the wood. While some of the treated surfaces were darker than the untreated wood the bright green colour of the copper naphthenate products was not obvious. After nine weeks, although the treated areas were obvious, the surface colour was similar to that of the untreated areas. Recoating the CD50 and copper naphthenate treated areas darkened the wood again, but the green colour of the preservatives disappeared quickly.

Chemical analysis of wood samples for copper after oven drying and acid digestion was by atomic absorption spectroscopy following the method in the American Wood Preservers Association standard A11-83. Boron samples were extracted in aqueous acid and the boric acid determined by titration following the method outlined in Vogel, 3rd ed. III-17, p 252. TCMTB was analysed by high-pressure liquid chromatography (HPLC). Identification and quantification were made by comparison of retention times and integrated peak areas with those of standards.

The surface samples were taken from three different aspects, an upper surface sample from one or two of the 45° struts, a vertical surface sample from one of the struts, and a horizontal sample from the upper surface of one of the transoms. The surfaces were all fissured or cracked, particularly the horizontal transom surfaces. This resulted in the 2-4 mm deep samples including cracks or fissures which were more than 2 mm deep. Hence, preservative which was trapped in or had been absorbed into the surface of fissures probably increased retention results for the 2-4 mm samples, giving the impression that a significant amount of the preservatives had penetrated sound wood. After only six days it is unlikely that significant penetration into sound wood had occurred and most of the preservative in the 2-4 mm samples would have been at the checks and fissures.

The minimum retention required in the H3 treatment specification (NZS) for copper naphthenate in oven dry wood is about 0.1% copper on a mass/mass basis (NZ Standard MP3640:1990). The American Wood Preservers Association requires a retention of 0.65 kg/m^3 (copper) for timber used away from ground contact. Table 3 shows that the retention achieved with the CN Emulsion was above that requirement in all of the 0-2 mm samples but well below it in the 2-4 mm samples. For the copper naphthenate in diesel mixture, two 0-2 mm deep samples and all of the 2-4 mm samples contained less than 0.1 % copper.

The American Wood Preservers' Association recommends a minimum retention in pine wood plywood treated with oxine-copper (the same active ingredient as is in CD50) of 0.32 kg/m^3, which is approximately equivalent to 0.015% copper on a mass/mass basis (Stokes et al. 1991). After a single coat the retentions in the 0-2 mm samples were relatively close to the amount required. The retentions in the 2-4 mm samples were well below the required level, even with application of a second coat and did not increase over the nine week interval between coats. This suggests that the copper element of the preservative did not diffuse far into the wood.

Tests on the efficacy of boron as a fungicide indicate that a retention of about 0.5% boric acid, on a mass/mass basis, is required to prevent decay (Morrell et al. 1992). The very high retentions achieved with Boracol 400 in both the 0-2 mm and 2-4 mm samples indicate that good protection will result and that a less concentrated solution could have been used to achieve the required retention. While the relatively high retention in the 2-4 mm samples indicates that there was some penetration into the wood, this is probably more from checks and fissures than from penetration into sound wood. There is also a question about the long-term retention of water-soluble preservatives such as boron, which are likely to leach from the wood. Very high initial application rates may be necessary if the retentions are to stay above the toxic threshold for fungi for several years.

The addition of water-repellent to Boracol may help to control boron leaching. The supplier suggested that the addition of water-repellent at concentrations of more than 10% could be used if future monitoring indicates that significant preservative loss has occurred.

The benzalkonium chloride is mainly in the Boracol formulation to keep the boron in solution, but it has fungicidal properties and was used as a commercial wood preservative in New Zealand for a short period. The levels in the Boracol solution are higher than were used for pressure treatment of pine, and the chemical is known to bond with wood and may provide additional protection near the surface, particularly if the boron is leached out.

TCMTB retentions required to stop common decay fungi in wood are 1.1-1.5 kg/m3 which is approximately 0.4% TCMTB on a mass/mass basis (Van den Eynde 1990). Tests in Australia showed that 0.5% TCMTB in sawdust was effective in stopping decay (Greaves 1977). The retentions in the 0-2 mm samples for the Busan 30L and the Busan Pole Gel were all well above this level but those in the 2-4 mm samples were all lower. Some loss of preservative by leaching is possible, but TCMTB should be more resistant to leaching than boron-based preservatives.

The day after the second coats of copper naphthenate in diesel and CD50 were applied, samples were taken from alongside the earlier sampling points on the recoated components. These were analysed in the same manner as for the initial samples. Analytical results from the second sampling are in Table 4.

The copper retentions in the second set of copper naphthenate in diesel samples were more than double those for the original samples. The second coating was applied over the original sampling point, and when the second set of samples was taken there were indications that preservative had penetrated along the grain from the first sampling point into the area that the second set of samples was taken from. This may have been responsible for the relatively large retention increases in the second set of samples, particularly in the 2-4 mm samples. Even after the second coat of preservative, the 2-4 mm samples had retentions of less than 0.1% copper.

Analysis of the second set of CD50 samples indicated an increase in copper retentions over the first samples but nowhere near the doubling which could have been expected when the amount of preservative applied was taken into account. This suggests that there may have been some preservative loss in the nine weeks between coats. The formation of sludge in the containers and crystals on the surface of the wood after the CD50 was applied, suggested that some of the ingredients were not in solution and did not penetrate into the wood. The crystals on the surface would have been vulnerable to washing off in periods of wet weather. The possibility that the copper had penetrated deeper into the wood than the sample depth was discounted because the 2-4 mm samples still contained only very small amounts of copper. The proportion in the 2-4 mm samples, compared to the outer surface samples, could have been expected to have increased by the time of the second sampling, if the copper had diffused into the wood. Copper retentions in the 0-2 mm surface samples were all above the recommended 0.015%.

3.3 INSERTED PRESERVATIVES

Treatments with inserted preservatives were carried out when the CD50 and copper naphthenate in diesel treated components were given a second coat, nine weeks after application of the initial surface treatments. When holes were bored into the stringers, internal shakes and some internal decay pockets were intercepted, particularly near the centre of the components. The holes only penetrated to about half the thickness of the stringers and were 100-150 mm apart.

There were shakes (internal cracks in the wood that develop while the tree is growing) at sample point 'A' but no decay. All other sample points had shakes and decay at the central hole, with the decay at 'C' being moderate-severe. The central hole at sample point 'E' followed what appeared to be an old inspection hole.

The moisture contents of shavings from the holes are shown in Table 5. These were all relatively low, below 60% and in some cases below 30%. Moisture contents below 30% may be a disadvantage with the Impel rods (Highley and Ferge 1995), which require moisture in the wood to dissolve the preservative rod and to facilitate the diffusion process. It is likely that some moisture was removed from the wood of the shavings by the heat generated as the borings were made, but this would have been a relatively small amount.

The amount of preservative used is also shown in Table 5. The holes bored into sound wood should have held about 25 g liquid preservative. Table 5 indicates that much more preservative was inserted into some of the holes. This occurred where there were internal defects and preservative was pumped into the holes until the cartridge was empty. It is likely that the extra preservative will have partly filled some of the voids in the centre of the stringer, thereby giving extra protection in decaying areas.

The holes bored into the stringers and the amount of preservative used were less than would normally be used in pole treatment. For internal decay treatment in poles, holes are bored downwards from the surface of the pole, not horizontally as was done in the bridge stringers. This provides a much larger preservative reservoir and extends the length of the pole treated.

The recommended rate for Impel rods is 210 g boric acid (two rods in each of three holes around the circumference at the groundline) for poles of less than 300 mm diameter and 280 g boric acid (two rods in each of four holes around the circumference at the groundline)for poles of more than 300 mm diameter. The recommended rate for Busan Pole Gel is 400 ml (4/16 mm diameter x 50 cm long holes) at the groundline. There is no recommended rate for CN emulsion for this type of use.

If the recommended amount of inserted preservative is there to protect about 600 mm of the length of a 400 mm diameter pole then the volume of wood being treated is about 75 litres or 0.075 m^3. This gives a loading of about 5.3 kg/m^3 for the Busan Pole Gel (0.8 kg/m^3 of TCMTB) and 2.6 kg/m^3 for the Impel rods (3.7 kg/m^3 of boric acid). The amount of preservative required to fill the holes in each bridge stringer would have given a preservative loading of 0.7 kg/m^3 over 0.3 m of the stringer length. This translates to active ingredient loadings of 0.1 kg/m^3 (TCMTB) for the Busan pole Gel, 0.01 kg/m^3 (copper) for the CN Emulsion and 1.0 kg/m^3 (boric acid) for the Impel rods. These are well below the mass/mass retentions required in wood to stop decay, if the preservative is distributed throughout the stringer cross-section. However, with liquids, the preservative is most likely to redistribute along shakes or voids caused by decay and be in much higher retentions in these areas. In some of the holes in the Waikino stringers, much more preservative was injected than was required just to fill the bored holes, and therefore preservative retentions may well have been higher than required over the short section of the beam treated.

With a solid preservative such as the Impel rods the amount of preservative inserted is limited to the size of the bored hole unless there is a large internal cavity. This limits the amount of preservative inserted to the volume of the bore holes, and distribution may be limited to wood in the immediate vicinity of the bored holes.

The plastic plugs used for the inserted preservatives were tapered and designed to fit a 14-16 mm diameter hole. They had a spiral thread on the outside and a square hole in the top to facilitate removal using a square key. These were driven in lightly with a hammer and provided a relatively tight seal with the wood.

4. Costs

4.1 COSTS OF SURFACE TREATMENTS

The approximate costs of the surface applied preservatives used are shown in Table 6. These include GST and were the price of the chemicals when purchased from the nearest local agent or retailer. It is likely that costs could have been reduced, particularly if chemicals were purchased in bulk or directly from the manufacturer, but their ranking according to $/m^2 is not likely to change.

The cost of application was also not measured. For the chemicals that were brushed on, the time taken to apply one coat was not obviously different. Differences in component size, surface condition and accessibility influenced application times far more than differences in ease of application. There may be some cost advantage in applying the liquid formulations using spraying equipment, compared to brushing them on, but this was not investigated.

The ranking, based on $/m^2 preservative cost, shows that CD50 and Busan Pole Gel were considerably more expensive than the other preservatives used.

CD50 is water-repellent, which may give it some long-term advantages over the water soluble formulations and on surfaces that are exposed to more severe weathering. The relatively high cost and the need to apply two coats make it less attractive and this could only be offset by a substantially better protective performance than achieved with other products.

The application rates for the Busan Pole Gel gave surface retentions which were well above those required to protect against decay fungi. Costs could be reduced by diluting the Pole Gel with water, a process sometimes used where it is being applied to surfaces, or by reducing the application rate, but Busan 30L gave adequate results at a much lower cost.

The cost of Boracol 400 was higher than the copper naphthenate products and Busan 30L but the retentions were much higher than recommended. A more dilute formulation could have been used and this would have reduced costs substantially. Offset against this is the potential for boron based products to leach back out of the wood, something that may be controlled by the water-repellent additive. There may also be a need for initial retentions to be higher to accommodating some preservative leaching.

The amount of CN Emulsion applied was less than the application rate recommended by the manufacturer but gave surface retentions which were above the minimum required for H3 treatment. Applying a 3-6 mm thick coating over the whole surface would have cost at least $23.00/M2. There are some practical difficulties applying CN Emulsion at the recommended rates, but the lower rates achieved in this trial may mean that recoating will be necessary much sooner than if the manufacturers recommendations had been followed.

Metallex in diesel, was one of the lower-cost preservatives but the need to apply two coats was a disadvantage. The recommended dilution rate was 1:3 Metallex:diesel and a lower dilution rate could have been used to reduce the need for a second coat. Metallex can be mixed with other organic solvents, and an oil carrier of higher viscosity, instead of diesel, would have helped to increase initial application rates and might also have improved long-term water-repellency. Rebrushing areas several times during treatment was also an option but this would have increased treatment costs.

4.2 COSTS OF INSERTED/INJECTED TREATMENTS

The costs of the inserted preservatives are in Table 6A. If the cost of the 25 g required to fill one of the bored holes is compared, the Busan Pole Gel (cartridge) costs $2.15, CN Emulsion costs less than 50 cents and Impel rods cost $1.85. This is slightly misleading because in terms of active ingredient in 25 g the Pole Gel has 3.75 g TCMTB, the CN Emulsion has 0.36 g copper and the Impel rod potentially 35 g boric acid. Theoretically the amount of wood that could be adequately treated for decay prevention with these amounts of active ingredient is equivalent to 0.94 kg for the Busan Pole Gel, 0.36 kg for the CN Emulsion and 7.0 kg for the Impel rod. These costs are based on the products as they were available at the time and could change substantially depending on whether bulk product or pre-filled cartridges were used for the two emulsions.

A better way of comparing costs would be to look at the suppliers recommendations for internal decay in poles. The suggested usages are 400 mL of Busan Pole Gel or eight Impel rods. If the same volume of CN Emulsion was used then it would cost $3.33, the Impel Rods would cost $14.80 and the Busan Pole Gel $34.48.

This suggests that there are substantial differences in preservative costs for the inserted preservatives, but the amount of active ingredient delivered and the ability of the treatments to diffuse through the wood are of prime importance. CN Emulsion is not likely to diffuse far into the wood, particularly if the wood is relatively wet. The boron rods probably need a moisture content above 30% to be effective but they deliver the most preservative on a mass/

mass basis. Busan Pole Gel (in cartridges) is the most expensive of the three but may be better able to spread through checks and voids inside the components and to diffuse into adjacent decaying wood.

5. Future monitoring

While some of the preservatives appear to have advantages associated with application, retention and cost, this project was established to measure their ability to reduce surface degradation and decay over a long period. The degradation of the very durable timbers used in the Waikino bridge has been quite slow, and visible differences between the treatments may not be apparent for several years. It is also likely that some of the preservatives will be retained in the wood better than others. Those with water-repellent properties may be better at reducing surface weathering than those which are not water-repellent. Therefore an assessment programme to monitor visual changes in the bridge, to measure surface depletion of the preservatives and their diffusion into the wood, is necessary. Results from this programme will be needed before a true evaluation of the costs and benefits of the treatments will be possible.

The inserted preservatives, to be effective, should gradually diffuse into the wood. The monitoring programme should include regular checks to determine how rapidly the preservative is dissipating and to replenish the reservoir holes when they are empty.

At this stage it is difficult to determine how frequently the bridge should be monitored, but a visual inspection and a check on the dissipation of the inserted preservatives would be advisable after six months. More detailed sampling to monitor preservative depletion and wood deterioration should initially be annually until some data on depletion and deterioration rates has been gathered.

Several of the structural members in the bridge, including some that were treated during this test, require replacement or reinforcement in the near future. Any treated timbers removed when the bridge is repaired should be retained by Goldfields Rail Inc. and stored in an open area where weathering can continue. This will allow data on preservative retention and wood degradation to be collected from the full range of components and treatments originally included in the test.

6. Conclusions

In terms of cost and meeting retention requirements, Busan 30L appears to give the best results for the surface treatments. It bonds with the wood relatively close to the surface and is unlikely to diffuse further into the wood. There is a significant health risk to workers applying Busan 30L.

CN Emulsion was more expensive than Busan 30L and is one of the more expensive preservatives if applied at the rate recommended by the manufacturer. It is less toxic than Busan 30L and less likely to splash or drip during application.

If a diffusible preservative is required or conditions are damp, Boracol is the least expensive and the cost could be reduced by using a less concentrated formulation.

Boron rods deliver the most active ingredient at the lowest cost for the inserted/injected preservatives. They may be less effective where the wood is relatively dry.

This report only evaluates the application and initial retention of the preservatives. A full assessment of their persistence and their efficacy in reducing the rate of deterioration is needed before any benefit resulting from their application can be evaluated.

7. Bibliography

Anon, 1992. Specification of the minimum requirements of the New Zealand Timber Preservation Council. New Zealand Standards Association, MP3640:1990.

Anon, 1999. American Wood Preservers' Association Book of Standards 1999. American Wood Preservers' Association, Granbury, Texas.

Greaves, H. 1977. Progress towards controlling softrot of treated hardwood poles in Australia. International Group on Wood Preservation, document WP 289.

Highley, T.L.; Ferge, L. 1995. Movement of boron from fused boron rods implanted in southern pine, Douglas fir, red oak and white oak timbers. International Group on Wood Preservation, document IRG/WP/95-30061.

Morrell, J. J.; Sexton, C.M.; Archer, K. 1992. Diffusion of boron from fused borate rods through selected woods. *Forest Products Journal 42* (7/8): 41-44.

Nicholas, D.D.; Schultz, T.P. 1995. Biocides that have potential as wood preservatives - an overview. *Forest Products Society Journal*, Article FPA-016-0195.

Stokes, D.K.; Nicholas, D.D.; Barnes, H.M.; Amburgey, T.L. 1991. Copper-8-quinolinolate: a pressure treatment alternative. American Wood Preservers' Association Proceedings, 1991

Van den Eynde, R. 1990. The use of TCMTB in applications other than sapstain prevention - A review. International Group on Wood Preservation, document IRG/WP/90-3606.

Table 1. Preservatives used.

Preservative	Active Ingredient	Carrier	Brushed On	Inserted
Busan 30L	TCMTB[1]	Water	Y	-
Busan Pole Gel	TCMTB[1]	Paste[2]	Y	Y
Metallex	Copper naphthenate	Diesel	Y	-
CN Emulsion	Copper naphthenate	Paste	Y	Y
Boracol 400RH	Boron[3]	Water	Y	-
Impel Rods	Boron	-	-	Y
CD50	Copper-8-quinolinolate	Oil	Y	-

[1] - 2-(Thiocyanomethylthio)benzothiazole

[2] - Paste includes "Busperse 47"® wood penetrant based on dimethyl amides of unsaturated fatty acids

Table 2. Preservative application details.

Application Sequence	Component Numbers Coated	Area Coated (m^2)	Preservative Used (kg)	Applied Rate (kg/m^2)	Required† Rate (kg/m^2)	Active Ingredient (g/m^2)*
CN Emulsion (KCNE)						
Day 1	8,	3.60	1.70	0.47	2.90	6.89
Day 2	12,24,24a,44	4.57	1.28	0.28		4.09
Day 3	3,17,17a,37	4.47	1.62	0.36		5.18
Busan 30L (B30L)						
Day 2	6,26,26a,36,46	5.52	2.14	0.39	NA	37.08
Day 3	7,9,19,19a,39	8.82	2.32	0.26		26.49
CD50						
Day 2	16,42	2.05	1.19	0.67	0.30	0.28
Day 3	1,	3.40	1.31	0.39		0.16
Day 4	14,22,22a	2.35	0.99	0.42		0.17
Recoat	1,14,16,22,22a,42	7.80	3.68	0.47		0.25
Metallex in Diesel (CNO)						
Day 3	11,23,23a,43	4.87	1.65	0.34	0.12	3.05
Day 4	2,18a,38	4.21	1.55	0.37		3.31
Recoat**	2,11,23,23a,43	8.27	3.00	0.36		4.05
Boracol 400 RH + Water-repellent (BORU)						
Day 3	5,25,25a,45	4.56	3.17	0.69	0.33	298.90
Day 4	10,20,20a,40	4.57	3.14	0.69		295.60
Busan Pole Gel (BPG)						
Day 3	13,15,21,21a,41	4.63	1.94	0.42	NA	56.63
Day 4	4,18	3.45	2.03	0.59		79.49

*Active ingredients are expressed as copper (CNO, CD50, and KCNE formulations), TCMTB (BPG and B30L) and boric acid (BORU)

† Manufacturer's suggested application rate.

**The compression block 38 and the upper transom surface 18a were not given a second coat with copper naphthenate in diesel. The average application rate/active ingredient rate was 0.35kg/m2 and 3.17g/m2 respectively for these components.

Table 2a. Preservative application details.

Preservative Code	Area Coated (m^2)	Preservative Used (kg)	Applied Rate (kg/m^2)	Required Rate (kg/m^2)	Active Ingredient (g/m^2)*
Total Preservative Application					
B30L	13.89	4.46	0.32	NA	30.70
BPG	8.08	3.97	0.49	NA	66.40
CNO	8.27	5.91	0.71	0.12	6.30
KCNE	12.73	5.04	0.40	2.90	5.78
BORU	9.13	6.31	0.69	0.33	297.15
CD50	7.80	7.17	0.92	0.30	0.43

*Active ingredients are expressed as copper (CNO, CD50, and KCNE formulations), TCMTB (BPG and B30L) and boric acid (BORU)

Table 3. Chemical analysis of surface samples - first application.

Component Number	Preservative	Surface Angle	Tag Number	Ingredient Analysed	Analytical Results (g/100g in oven dry wood)	
					0-2mm	2-4mm
12	KCNE	45	B 0380	Copper	0.231	0.024
12	KCNE	90	B 0384	Copper	0.273	0.022
24	KCNE	0	B 0379	Copper	0.109	0.003
3	KCNE	45	B 0383	Copper	0.268	0.007
11	CNO	45	B 0376	Copper	0.083	0.012
23	CNO	0	B 0375	Copper	0.048	0.005
2	CNO	45	B 0389	Copper	0.127	0.030
2	CNO	90	B 0386	Copper	0.112	0.031
1	CD50	45	B 0391	Copper	0.021	0.004
1	CD50	90	B 0378	Copper	0.010	0.003
16	CD50	45	B 0388	Copper	0.011	0.007
22	CD50	0	B 0398	Copper	0.013	0.005
9	B30L	45	B 0393	TCMTB	1.396	0.458
9	B30L	90	B 0400	TCMTB	1.159	0.182
26a	B30L	0	B 0385	TCMTB	0.743	0.144
15	BPG	45	B 0382	TCMTB	1.584	0.321
13	BPG	90	B 0373	TCMTB	1.493	0.252
21	BPG	0	B 0394	TCMTB	0.753	0.076
5	BORU	45	B 0374	Boric acid	4.340	0.957
5	BORU	90	B 0397	Boric acid	2.800	0.545
25	BORU	0	B 0390	Boric acid	2.315	0.645
10	BORU	45	B 0381	Boric acid	3.380	1.090

Table 4. Chemical analysis of surface samples - second application.

Component Number	Preservative	Surface Angle	Tag Number	Ingredient Analysed	Analytical Results (g/100g in oven dry wood)	
					0-2mm	2-4mm
11	CNO	45	B 0376	Copper	0.242	0.057
23	CNO	0	B 0375	Copper	0.127	0.033
2	CNO	45	B 0389	Copper	0.220	0.079
2	CNO	90	B 0386	Copper	0.183	0.052
1	CD50	45	B 0391	Copper	0.022	0.007
1	CD50	90	B 0378	Copper	0.019	0.005
16	CD50	45	B 0388	Copper	0.016	0.010

Table 5. - Inserted preservative treatment details.

Sample Point	Boring Position	Green Weight (g)	Oven Dry Weight (g)	Moisture Content %	Preservative Used	Amount Used (g)	Wood Condition
A	Top	21.15	16.56	27.7	Impel	25	Sound
A	Middle	17.22	13.20	30.4	Impel	25	Sound
A	Bottom	22.90	17.92	27.8	Impel	25	Sound
B	Top	17.87	13.63	31.1	BPG	150	Shakes
B	Middle	23.07	17.49	31.9	BPG	150	Centre rot
B	Bottom	24.21	17.76	36.3	BPG	25	Shakes
C	Top	23.62	18.27	29.3	KCNE	25	Black
C	Middle	2.74	2.28	20.2	KCNE	150	Severe rot
C	Bottom	23.95	18.10	32.3	KCNE	150	Shakes
D	Top	20.29	14.25	42.4	Impel	25	Shakes
D	Middle	21.94	14.30	53.4	Impel	25	Centre rot
D	Bottom	25.78	19.01	35.6	Impel	25	Sound
E	Top	19.71	15.41	27.9	KCNE	25	Sound
E	Middle	8.93	6.58	35.7	KCNE	50	Rot -old hole
E	Bottom	20.99	16.83	24.7	KCNE	25	Sound
F	Top	20.53	15.87	29.3	BPG	25	Sound
F	Middle	7.17	5.08	41.1	BPG	250	Centre rot
F	Bottom	22.02	16.87	30.5	BPG	25	Sound

Table 6. Total surface-applied preservative costs.

Preservative	Pack size Purchased	Preservative Cost	Usage (kg/m^2)		Cost ($\$/m^2$)
			Actual	Required	
Busan 30L	1 litre	27.50/litre	0.32	NA	2.94
CN Emulsion	20 kg	8.29/kg	0.40	2.90	3.32
Metallex/diesel†	1 litre	5.63/litre	0.71	0.12	4.79
Boracol 400RH*	20 litre	20.80/litre	0.69	0.33	10.82
Busan Pole Gel	20 kg	35.75/kg	0.49	NA	17.52
CD50†	4 litre	23.00/litre	0.92	0.30	24.89

* Does not include the cost of water-repellent additive.
† Includes both applications.

Table 6A. Inserted/injected preservative costs.

Preservative	Pack Size Purchased	Preservative Cost $	Retention Required (g/100g)*	Cost** ($/kg)
Impel rods	Sample	1.85 (each)	0.5	0.26
CN Emulsion	†Cartridge	2.75 (each)	0.1	0.57
Busan Pole Gel	Cartridges	28.45 (each)	0.4	2.30
Plastic plugs	Sample	0.27 (each)		

*Retentions are in active ingredients, boric acid for Impel rods, copper for CN Emulsion and TCMTB for Busan Pole Gel.

**The cost of treating one kilogram of oven dry wood to the required retention.

†The CN Emulsion cartridges were hand filled from a bulk container as required. The value shown is the preservative cost from a 20 litre container only.

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