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PART A
Timber Pile Preservative Injection System.

and

PART B
Earth Bonding of Reinforcing Cages on Older Concrete Poles.

Author and Presenter

Wal Marshall

Director
LineTech Consulting Ltd

PART A: Timber Pile Preservative Injection System

A1: Background

There are many bridges, transmission towers and other structures built on driven timber piles. As they age, it is often difficult to maintain the piles as they are costly to excavate or in some cases excavation is impractical.

Transpower has a number of 1930-1960's era transmission line towers built on timber piled foundations. Generally these are located at or close to river or other waterway crossings. The piles are invariably Australian hardwoods, typically ironbark, black butt or spotted gum. The foundations usually consist of three timber piles on each corner of the tower, a total of 12 piles per tower. Each group of three piles is capped with a concrete block approximately 2 m deep, which in turn is bolted to the bottom of the tower leg. **(Photos 1 and 2)**

A2: Example Problem:

On the Transpower Bunnythorpe to Haywards A and B 220kV lines, there are a number of timber piled foundations approaching 50 years old, and concerns were held as to the condition of the timber piles. Complete replacement of the foundations was being considered.

A sample foundation at the Waikanae River was excavated to ascertain the condition of piles. They were found to be in remarkably good condition considering their age and all were still physically sound. Some piles were solid right through, but a more typical condition was a soft outer layer of about 5-10 mm (30 mm where sapwood had not been removed), a sound timber body of 70- 100 mm or so, then a softer decomposing core of poorer quality heart wood. Sometimes the soft core was dry but more typically it was damp/wet and smelled strongly of alcohol indicating advancing core rot. The upper section of the piles directly beneath the concrete capping was in the worst condition, presumably because it was exposed to the most oxygen.

Photo 1: Excavating a foundation.

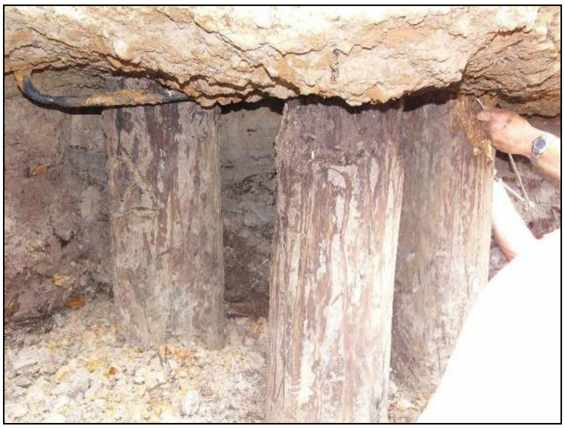

Photo 2: Three timber piles under the concrete

A3: Preservative Injection System

With the discovery that the piles were still sound, thoughts moved to whether their life could be extended and if so how this could be achieved. Since core rot was the major problem, and excavating the piles was costly (and the introduction of oxygen each time ultimately would case accelerated deterioration), a system was designed to allow injection of preservative into the core of the piles without the need for regular excavation.

The system consisted of three basic components-

a) An injection block bolted to the tower leg. This was a mild steel block with three grease nipples on the top, connected to three outlets on the bottom**,** bolted to the tower leg with two x 12 mm bolts. **(Photo 3)**

b) Three injection lines. These were made of approx 3 x 6m lengths of 3/16 inch copper-nickel automotive brake tubing, terminated at each end with line flares and tube nuts.

c) Three injection screws. These were fabricated from 16 mm coach screws drilled right through and threaded through the head to take a brass adapter and tube nut to terminate the brake line. **(Photo 4).** The coach screws were installed in 16 mm holes drilled into the side of each pile.

Photo 3: Injection Block

Photo 4: Injection Screws

A4: Installation

During March 2006, ten towers (120 piles) on the Bunnythorpe Haywards A&B lines were fitted with the preservative injection systems. To install the system, each foundation was opened up with an excavator, the hole dewatered and each pile was inspected and drilled to establish current condition. The inspection hole was then fitted with an injection screw, an injection line was attached to each one, and terminated at the top onto the injection block bolted to punched holes in the tower leg. Preservative was then injected into each pile while the line and pile were inspected for leaks. The foundation was then back filled.

The injection blocks were mounted approximately 800 mm above the tower foundation pad at a comfortable working height. Injection lines were run as a group down the leg, across the pad and down the foundation block tied together with cable ties. The injection nozzles were installed approx 300 mm below the bottom of the concrete pile caps at approx 2-3 m below ground level, depending on the particular foundation. (Concrete depth varied from foundation to foundation). At this depth the injection points are well below the water table level on all towers even in summer. The total length of line required from injection nozzle to injection block on the tower leg varied from 4 -6 m per pile. (**Photo 5**)

Photo 5: Injection lines installed and external pile surface coated with preservative.

Installation proceeded smoothly although great difficulty was encountered in trying to dewater some sites due to the gravelly free draining soils and the close proximity of the local rivers. Some sites required four x 3 inch pumps plus two x 6 inch pumps working in parallel, and even then linemen were sometimes working up to their waists in water .

Initially it was attempted to pump the preservative into the piles using a manually operated grease gun. However this proved ineffective as the "CN Emulsion" used was too thin to enable the guns to operate effectively. It was also very messy to load them.

A compressed air driven grease pump was then purchased to pump the preservative into the piles, and proved to be ideal for the job. (**Photo 6**). This enabled the CN Emulsion preservative to be drawn directly from the original pails, and injected into the piles under considerable pressure.

Photo 6: The preservative injection pump.

Photo 7: Internal preservative oozing out a grub hole.

The piles responded to the preservative injection in one of three ways:

1. On approx 50% of the piles pumping refusal was reached, typically between 30-50 strokes of the pump, or about 200 ml of preservative.

2. On approx 30% of the piles, the pile continued to accept preservative even after 50 strokes, but the rate of acceptance was very slow. This typically happened where piles had significant core rot voids and the preservative was slowly forcing it's way into the core of the pile, displacing moisture. Over 500 ml of preservative went into some piles.

3. On approx 20% of the piles preservative continued to feed in at a relatively high rate. Usually this suggested that the pile itself had opened up a split or had other defects enabling preservative to leak out somewhere. These were usually obvious to visual inspection. (**Photo 7**)

Six months after the installations were completed, each foundation was revisited and further preservative injected. It is planned to do this approximately 12 monthly here after.

Overtime it is envisaged that the injected preservative will migrate throughout the piles, not only through the softer and more deteriorated core rot regions., but also gradually though the harder timber to reduce deterioration in the outer parts of the pile as well.

A5: Conclusions

Preliminary indications following installation of the injection systems is that they will indeed considerably increase the service life of the piles.

After the piles have been in service for another 10 years it is planned to sample excavate a number of them to recheck their condition.

The author wishes to acknowledge Transpower NZ Ltd for approving the publishing of this paper, and United Group Ltd Upper Hutt who were contractors for the installation of the injection systems.

PART B: Bonding of Reinforcing Cages on Older Concrete Poles.

B1: Background

All new transmission strength concrete poles are manufactured with "integral earthing systems". This means the pole is built with an earthing system within the pole wall connected to ferrules on the pole surface, to enable crossarms and earthwires to be bonded into the earthing system. The earthing system runs the length of the pole, and ensures the pole reinforcing cage and all accessories on the pole remain at a uniform potential at all times. This ensures a reliable operating and a safe working environment.

However some older transmission concrete poles were not fitted with an integral earthing system. To ensure operational reliability and prevent damage to the poles and crossarm bolts, Transpower have retrofitted these poles with an external earthing system. This system consists of a copper XPLE cable connecting the pole top earthwire and crossarms to a ground driven earthing electrode. It does not however connect to the pole reinforcing cage. While an external earthing system has ensured operational integrity, safety issues have emerged during portable earthing.

This paper looks at methods to achieve a bond between the external and internal earthing systems.

B2 Whats the Actual Problem?

During portable earthing, conductors, crossarms, and other pole top metal must be bonded to form an equipotential zone for a worker mounted on the pole. This earthing arrangement is connected to a pole cluster and then to a driven earth rod. This creates an equipotential zone. The difficulty is that the concrete pole structure itself remains at the potential of the reinforcing cage which is earthed to some extent through the pole foundation. The critical issue is that the external earthing system (permanent or temporary) is not connected to the same earth point as the pole itself because there is no solid low resistance connection between the two. Thus it is possible (probable) that during a fault (for example a phase is livened), the external system will rise above earth potential to some extent while the pole structure itself (separately earthed and carrying little or no fault current) remains at a somewhat lower potential. The voltage difference between the two could be of the order of several kV and is definitely hazardous.

A worker mounted on the pole and (say) unbolting a crossarm, will have his hands in direct contact with the pole external earthing system. His body, legs and feet however maybe in intimate contact with the pole surface/pole steps. During a fault the workers body will rise in voltage with the external earthing system, creating a risk that fault current could pass from the worker through the pole into the internal reinforcing cage which may remain at a lower potential.

The best way to eliminate this potentially hazardous portable earthing environment, is to bond the pole cage into the external earthing system. (There are also other mitigating options available, such as working entirely off bucket trucks, but at transmission voltages and pole heights this can present other difficulties.)

In the Transpower system there are two dominant concrete pole designs which have been permanently fitted with an external earthing system. One is a hollow spun pole made by Unicast in Hastings. The second is a large Vierendeel design made by Stresscrete. Both poles are prestressed designs with prestressing strands running the full length of the pole.

The two pole designs were examined for ways to bond into the reinforcing cages.

B3: Vierendeel Bond Design

The Vierendeel pole has a fortuitous design feature that makes bonding the pole cage relatively easy. Because the pole section changes at ground line, during manufacture the prestressing strands have to be tensioned across a steel bridge positioned within the pole at the ground line to hold the strands apart. This bridge remains in the pole after fabrication but serves no useful structural role. However from a pole bonding point of view, the bridge is not only in intimate contact with all the prestressing strands, it is also substantially constructed using 25 mm dia or larger steel rods. Therefore it is possible to drill into the pole and connect to the bridge steel work and thus connect to all the prestressing strands. To check this assumption, a sample pole was drilled and the resistance from the bridge to the ends of the prestressing strands measured. This proved to be zero to all six strands. The preliminary design of the bond connection is shown in **Diagram 1** below.

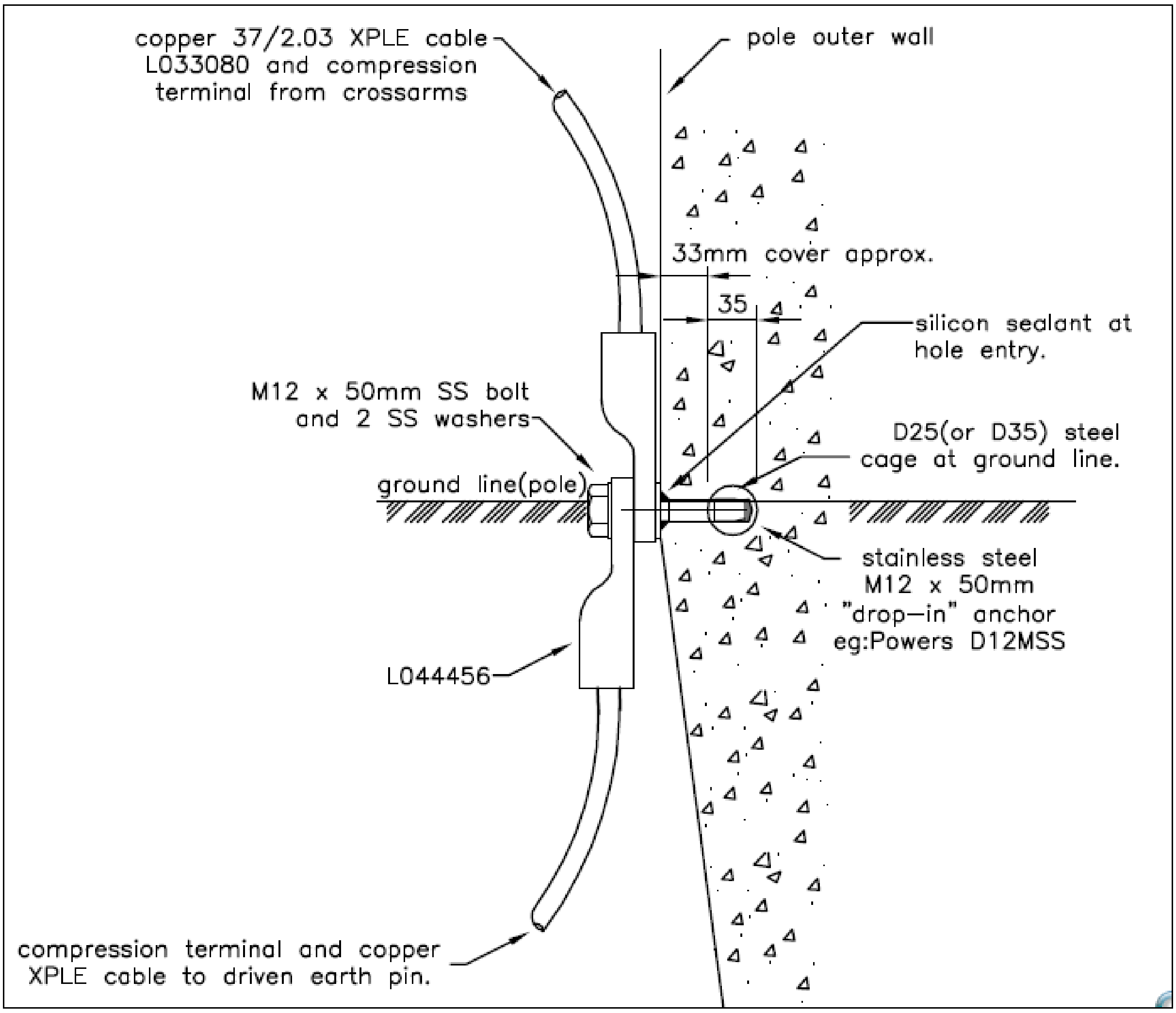

Diagram 1: Tentative bonding bracket details for Vierendeel poles.

B4: Hollow Spun Pole Bond Design

Connecting to the hollow spun pole proved to be more difficult. The cage consists of 10-14 x 9.5 mm prestressing strands uniformly spaced around the pole wall, with 3 mm dia spiral binding wire wrapped around the prestressing for the whole pole length. The pitch of the binding wire wraps is approximately 120 mm.

To open up the pole wall so as to expose any length of prestressing strand near ground line was considered as potentially compromising the structural strength of the pole. Therefore it was decided to try connecting to the outer spiral binding instead. The binding runs the whole pole length and has multiple contact points with each of the prestressing strands. A sample pole was checked by opening up the binding, and the resistance from the spiral binding to every one of 14 prestressing strands was measured as zero ohms.

To connect to the spiral binding wire however is problematic due to its small size (3 mm dia), so it was decided to design a bonding bracket that made two points of contact, and thus create 4 outgoing paths. This provides a current carrying cross section equivalent to a 6 mm dia steel rod embedded in concrete and therefore although small has good heat dissipation potential.

The tentative design of the bonding bracket is shown in **Diagram 2** below.

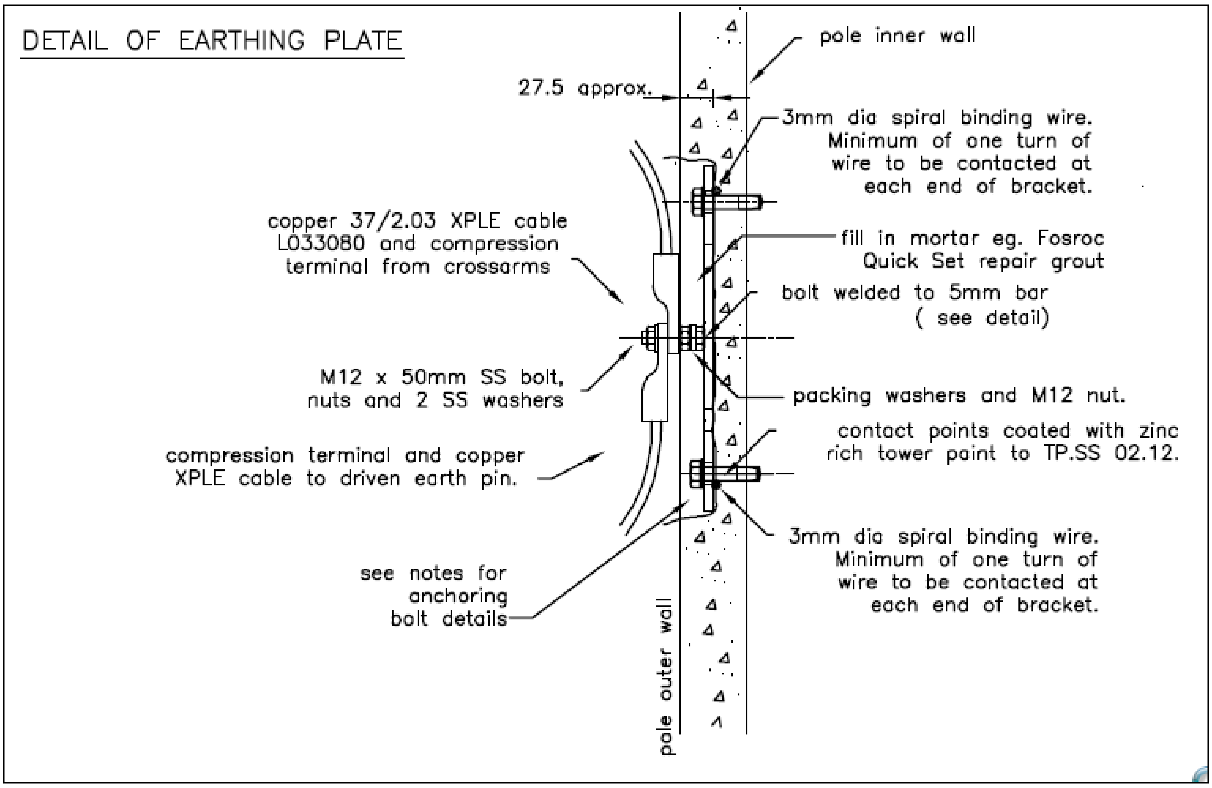

Diagram 2: Tentative Bonding Bracket Detail for Hollow Spun Poles.

The pole wall is cut vertically to form a channel approx 35 mm wide, 20 mm deep and about 200 mm long. The concrete is then chipped away to expose two turns of spiral binding. The earthing bracket is then bolted tightly across the exposed binding wire with the contact points impregnated with Transpower 95% zinc rich tower paint to optimise and seal the contact area. The bracket slot is then refilled with high strength quick setting grout. (**Photo 8**)


Photo 8: An early prototype bracket installed on a hollow spun pole, prior to reinstatement with mortar.

B5: Planned Development Work

At the closing date for this paper, (7 April 08), the following work was underway to prove and develop the bond designs.

a) Both bond designs will be high current tested to determine their capability. The tests are planned to be conducted on 1.5 m sections of the two pole types in May 08.

b) Several in-service poles will have bonding points installed, to test and refine the installation techniques. This will include measuring the resistance to remote earth of the driven pole earths, vs the pole earth itself. The results of this data will provide insight into what the current sharing ratio is likely to be between the pole earth and the driven earthing pin.

Once all the test data is to hand, a decision can be made as to whether the pole earths are

- Robust enough to be permanently connected into the existing external earthing system, (preferable) or
- Too limited in capacity and thus left disconnected during normal operation, and connected only when workers are on the pole and portable earths are installed.

An update on progress with this work will be provided during the conference presentations in June.

B6: Tentative Conclusions

Subject to high current testing and field refinement of the design and installation it seems probable that:

a) Effective earth bonding to the reinforcing cages of at least two types of concrete poles is achievable.
b) Installation costs of the bonds are likely to be of the order of $100-300 per pole, but may be less with further refinement, especially when installed in bulk.
c) The bonds will not likely withstand extreme fault duties but should be adequate to bond in the cages when installed in parallel with an external earthing system.

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