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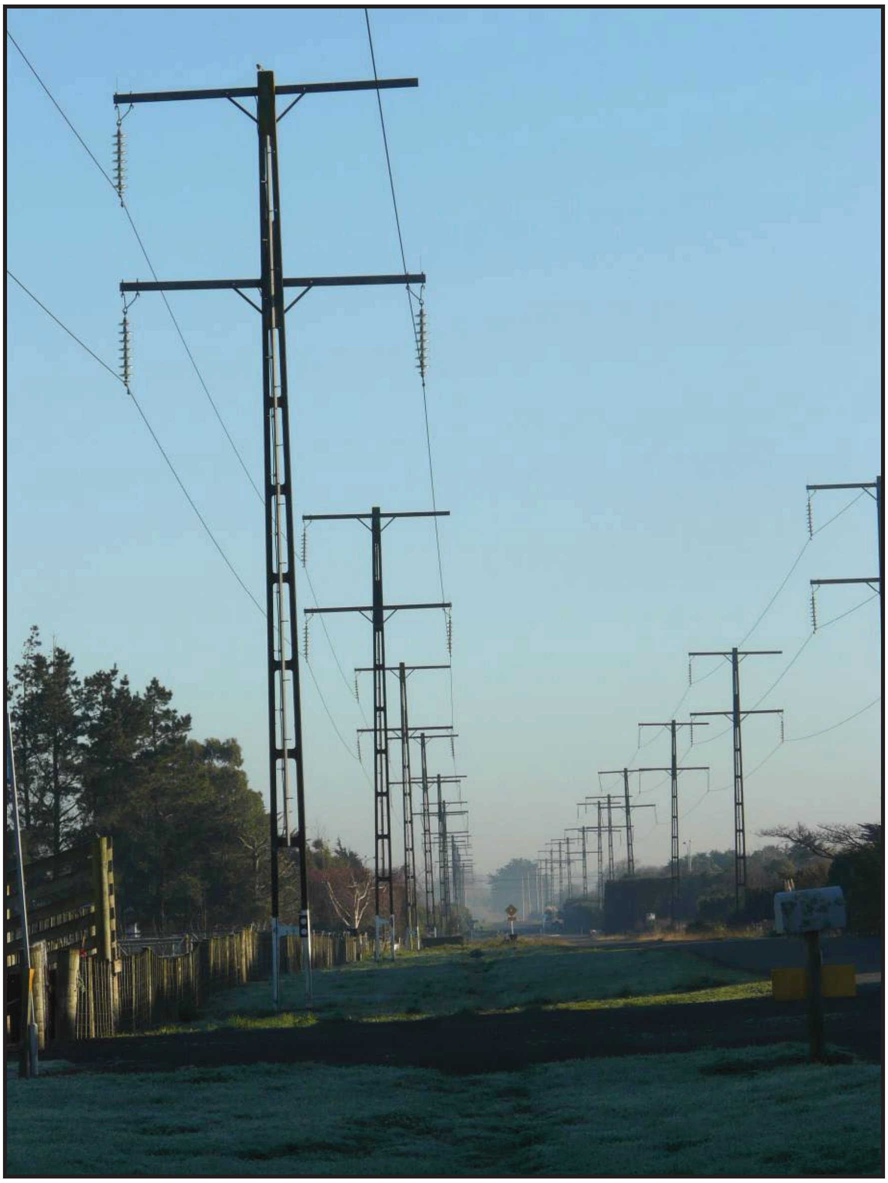
Earth Bonding of Reinforcing Cages on Older Concrete Poles: Part 2



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Bonding of Reinforcing Cages on Older Concrete Poles: Part 2

This paper updates an earlier paper presented to the 2008 EEA Conference.
It adds new information on high current testing and field installation experience.

1. BACKGROUND

All new transmission strength concrete poles (and now many distribution strength poles) are manufactured with "integral earthing systems". This means the pole is built with an earthing system within the pole connected to ferrules on the pole surface. This enables crossarms, earthwires and other pole mounted equipment 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 many older 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 their older poles with an external earthing system. This system consists of an externally mounted 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.

2. 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 on a concrete pole the 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 exact 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 incorrectly 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.

3. BONDING DESIGNS

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

3.1 Vierendeel Poles

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.

A design was created using a masonry anchor embedded into the pole. The design of the bond connection is shown in **Figure 1** below.

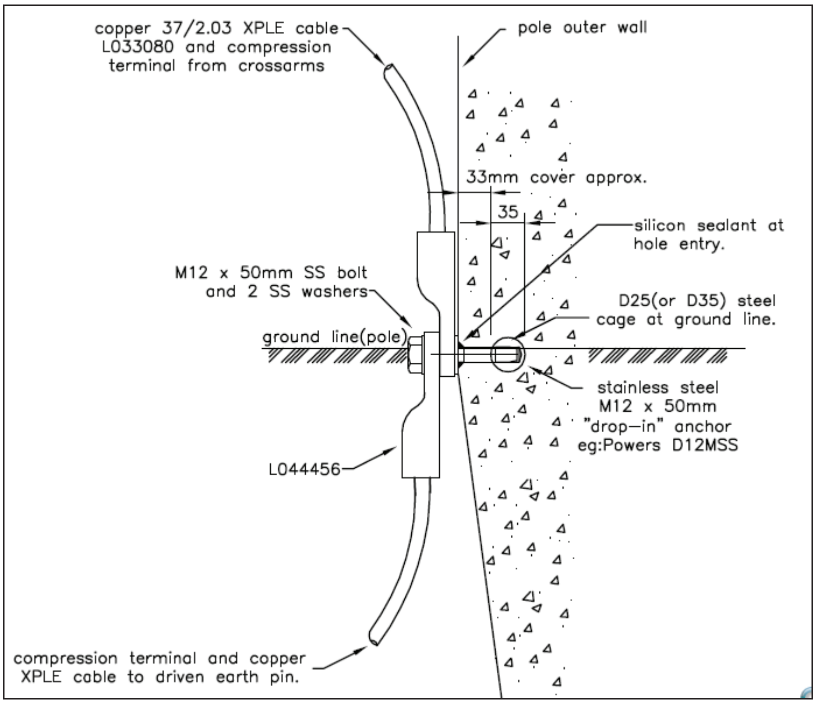

Figure 1: Bonding details for Vierendeel poles.

Three test samples were created and subjected to high current testing.

Photo 1: High current testing Vierendeel pole cage bond, with connection bolt white hot.

The design proved to be very durable, and withstood approximately 10,000A for 0.5 seconds, limited only by the capacity of the connecting bolt. (Photo 1)

This design was passed for trial field installation. (Paragraph 4 of this paper)

3.2 Hollow Spun Pole Design 1

Connecting to the cage in the hollow spun poles has proved to be more difficult.

The pole cage consists of 10-14 x 9.5 mm prestressing strands, uniformly spaced around the pole circumference and running the length of the pole. There is 3 mm dia spiral binding wire wrapped around the prestressing for the whole pole length. The pitch of the binding wire wraps varies but averages approximately 120 mm. The pole wall is relatively thin and averages 40-50 mm thick.

There are just two basic connection options- connect to the prestressing strands and/or connect to the spiral binding wire. In addition there is the issue of whether to connect at ground line or connect at the pole top. For ease of access, speed of work and ease of testing/maintenance, the most attractive option is to connect at ground line.

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 <1 ohm.

Connecting to the spiral binding wire however is problematic due to its small size (3 mm dia), so a bonding bracket was designed that made two or more points of contact, and thus creating 4 outgoing paths. This provides a current carrying cross section equivalent to a 6 mm dia steel rod embedded in concrete (and with excellent heat dissipation potential).

The design of the planned bonding bracket is shown in **Figure 2**.

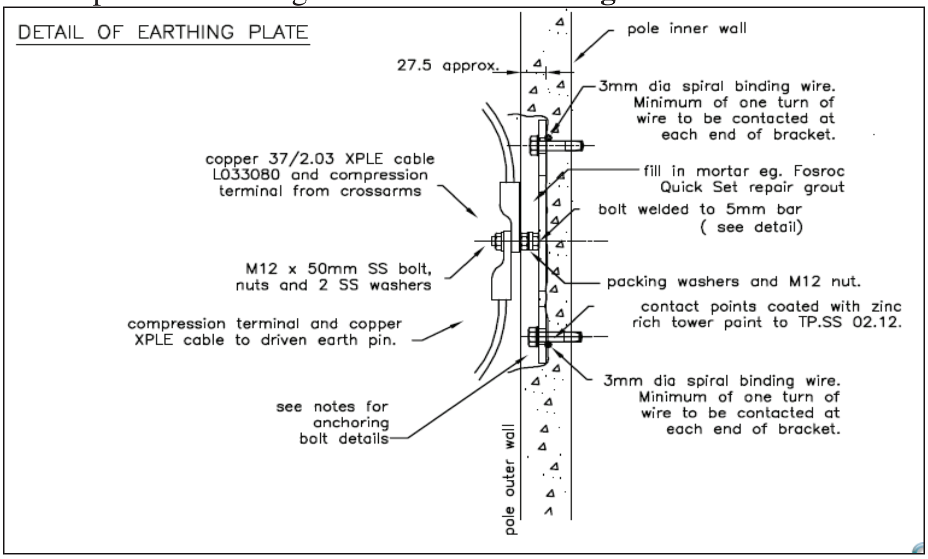

Figure 2: Tentative Bonding Bracket Detail for Hollow Spun Poles.

The pole wall was cut vertically with a concrete saw to form a channel approx 35 mm wide, 20 mm deep and about 200 mm long. The concrete was then chipped away to expose two or more turns of spiral binding. The earthing bracket was 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 was then refilled with high strength quick setting grout.

Photo 2: Earthing bracket for Hollow spun pole, prior to grouting, showing connection to two binding wires.

Photo 3: Test setup hollow spun poles

Three samples were subjected to high current testing. The results were disappointing with all samples open circuiting at low current at the internal connections, as shown in Table 1

Table 1: Hollow Spun pole testing: Design 1			
Sample	**Design**	**Max fault current**	**Result**
1	2 spiral turns contacted	400A for 0.5 sec	Open circuit
2	3 spiral turns contacted	800A for 0.5 sec	Open circuit
3	4 spiral turns contacted	500A for 0.5 sec	Open circuit

Design 1 was therefore rejected, and an improved design looked for.

3.3 Hollow Spun Pole (Design 1A \and Design 2)

Design 1A is under development as this paper was being written, This essentially consists of the same concept as design 1, but with an improved connection between the spiral binding and the bonding bracket. The most promising option is to load the contact face of the bonding bracket with a thick layer of solder, and coat the spiral binding wire with paint on solder flux. After the bracket is bolted to the pole, the assembly will then be heated just enough to just melt the solder near the contact points and pull them into intimate contact with the binding wire thus obtaining a much improved soldered joint.

An update on progress will be given in the conference presentations.

If design 1A ultimately doesn't work, then Design 2 will be tried.

This abandons the idea of connecting to the spiral binding at ground line, and instead involves climbing the pole to connect to the prestressing strand at the pole top. The basic idea is to use an air chisel to chip away a small section of the concrete under the pole cap, and connect to the end of one of the prestressing strands. Options for the connection include a bolted clamp, a Cadweld joint or a compression sleeve.

4: FIELD WORK: VIERENDEEL POLES

Once the Vierendeel pole bonding design had passed the high current testing, work began on a trial field installation of 12 poles to test the install practicality of the design.

The initial proposal to use a compressed "C" ring compression connection to the earth rod was replaced with a more electrically robust Cadweld connection , but otherwise the design was installed as planned.

A section of poles in Rongotea Road near Palmerston North was chosen because they were close to the line depot and easily accessed from the side of the road.

The trial installs were completed but exposed two problems to be resolved.

a) Drilling a hole into hard concrete AND steel created problems. Diamond tipped bits were excellent for drilling the concrete, but very poor in penetrating the steel rebar. High speed steel bits would drill the rebar, but were blunted by the concrete. Two different diamond bits were tried but still nearly an hour was required to drill through the steel bar.

Photo 4: Diamond drilling a Vierendeel pole.

Still to be tested is a high performance diamond drill from the USA plus a purpose designed "Rebar cutter", (Figure 3) either of which was likely to drastically improve drilling productivity.

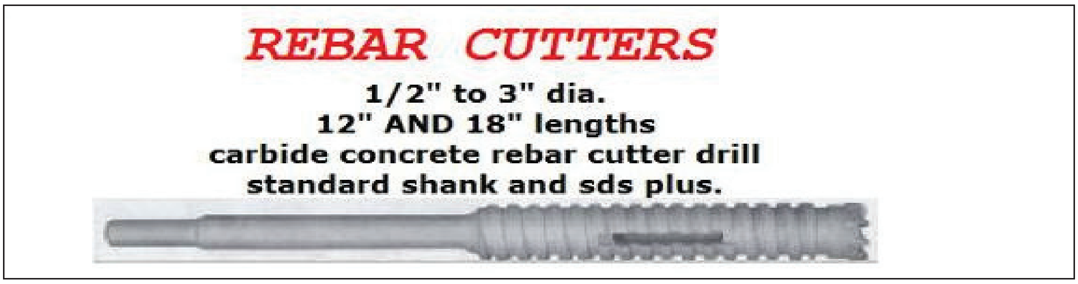

Figure 3: Specially designed rebar cutter tool.

b) The Cadweld connection to the existing driven copper clad earth-rod proved problematic because the taper at the top of the rod causing leakage of weld material.

Photo 5: Cadweld joint to earth-rod, showing excessive weld material leakage due to the taper at the top of the rod.

Careful modification to the casting mould and attention to mounting detail has solved that problem.

5. Summary

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The activities reported in this paper are obviously a work in progress. However it has already been shown that:

a) The cages of concrete poles are effectively electrically interconnected within the pole, thus connecting to any of the cage effectively bonds to whole cage.
b) Effective bonds to Vierendeel poles are possible where they have a ground line bridge (many distribution size poles also have the ground level steel bridge cages.)
c) Bonding to spun poles presents greater challenges but work is continuing and they are likely to be overcome.

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