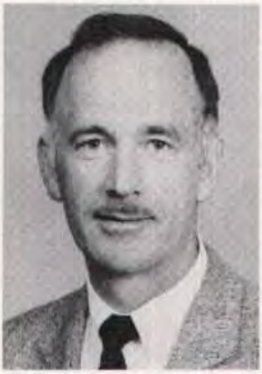
Production and Erection of Prestressed Concrete Poles for a Railroad Electrification Project



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During the oil crisis of the 1970s the New Zealand Government committed itself to doing all it could to reduce the effect on the country of future rises in oil prices. One of the options at that time was to convert the most heavily trafficked section of the New Zealand Railways Corporation system from diesel powered to electric locomotives.

In 1981 the decision was made to electrify a major part of the North Island main trunk line. While in this time of lowering world oil prices and rising electricity costs the initial economics may be hard to justify, the long term advantages of the scheme will benefit both the Railways Corporation and the country in the future.

The section to be electrified, through the center of the North Island, contained many steep grades through difficult terrain. In addition to the savings in imported fuel, electric locomotives offered the additional advantages of better tractive power on the steep sections of track, resulting in longer trains hauling greater loads, increased reliability and improved operating efficiency. Electric locomotives also have the advantage that regenerative braking on the downhill runs can be used to power other locomotives on the system.

In 1983 bids were called worldwide for the electrification of a 172 km (108 mile) section of track using a 25,000 volt alternating current system. This project was split into several contracts: Locomotives, Signals and Communications, and Traction Overhead (catenary cables and support structures). Local contracts were also let for track realignment, tunnel alterations and general upgrading of the line.

Included in the pole supply bid conditions was the option for the New Zealand Railways Corporation to extend the Stage I contract to Stage II, a further 230 km (144 miles) of track.

The contract for the Traction Overhead portion of the project, valued at NZ$35,000,000 (US$20,000,000), was won by a joint venture company: McConnell Dowell Constructors Ltd from New Zealand and Multi Construction Engineering Ltd from Australia. The McConnell Dowell — MCE Joint Venture awarded a subcontract to Firth Stresscrete, a division of Firth Industries Ltd, for the design and supply of the prestressed concrete poles.

Synopsis

A long line production method for producing prestressed concrete poles to support overhead catenary wires for a railroad electrification project has been developed in New Zealand.

The method is ideally suited to producing poles economically from a conventional multiproduct pretensioned precast concrete factory using semiskilled labor.

This paper describes the evolution of the design concept, optimum pole shapes, quality assurance, production and installation methods.

Electrical System

The prestressed concrete poles support a combination of conductors suspended from a steel framework. The 25kV system comprises five conductors: the earth wire connected to the back of the pole, the protection wire separated from the pole by two 3kV porcelain insulators, the auto-transformer feeder wire supported from a 25kV insulator and the contact and the catenary wires suspended over the middle of the track from a steel tube frame with 25kV insulators at its end.

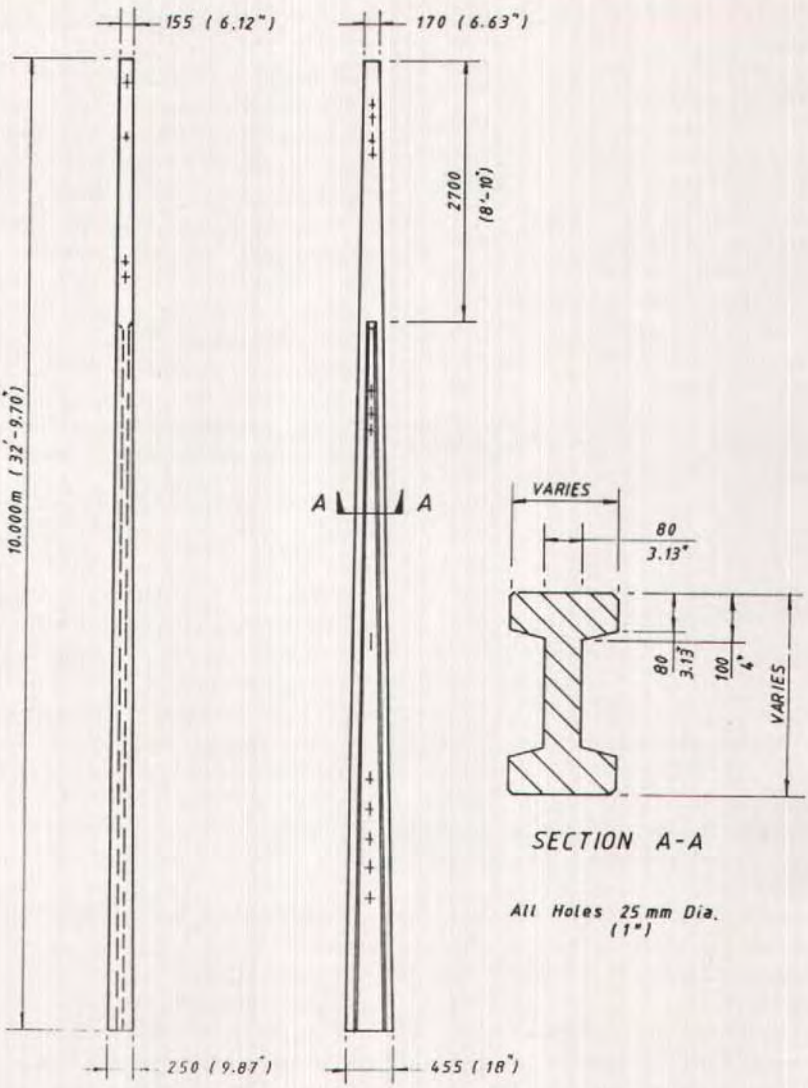
All the conductors, with the exception of the earth wire, are insulated from the pole's "earth potential" by the 3kV stand-off insulator between the pole and the rectangular hollow steel stand-off tube. The stand-off tube allows for height adjustments to the cantilever arm when registering the equipment.

Pole Options

Preliminary discussions with the New Zealand Railways Corporation had indicated that approximately 4000 poles would be required for Stage I and a further 6000 poles for Stage II. Since there seemed little likelihood of further sections of track being electrified, a production process that could produce 10,000 poles over a 4-year period was all that was required. Because of the relatively small number of poles, Firth Stresscrete felt that a sophisticated special purpose factory to produce the spun hollow circular poles that are used in other electric rail systems around the world could not be justified for this contract.

The company chose, therefore, to base its bid on a pole that could be manufactured in any of its existing prestressing factories along the route of the electrified track. The method chosen had to fit on existing long line pretensioning beds, be able to use concrete from a ready mixed concrete truck, and not require any production plant or labor skills that are not normally associated with the production of structural precast pretensioned concrete flooring or bridge units.

The bid specification provided a number of material options for the poles: steel, timber and concrete. All alternatives were investigated by the contractor



NOTES AND DESIGN LOADINGS

Pole Length	10.000 m.	(32'- 9.70")
Transverse W.L.	6.80 KN	(1530 lbs.)
Down Line W.L.	1.70 KN	(380 lbs.)
Load Applied From Top at	305 mm	(1'-0")
Safety Factor at W.L.		x 2
Ground Line	2000 mm	(6'-7")
Weight of Pole	1100 kg	(2424 lbs)

Fig. 1. Front and side elevations, cross-sectional details, design loadings and other particulars of Pole Type 510C 10 m (32 ft 9.70 in.).

and the New Zealand Railways Corporation, taking full account of both the electrical and structural properties of the materials.

The final decision in favor of prestressed concrete was based on this material offering the most economical solution, together with an aesthetically pleasing appearance when combined with the overhead equipment.

Pole prices in Firth Stresscrete's NZ$3,000,000 (US$1,700,000) pole supply contract ranged from NZ$150.00 (US$84.00) per pole to NZ$190.00 (US$106.00) per pole for the typical poles, and up to NZ$350.00 (US$196.00) per pole for the special poles.

Design and form costs were covered by a separate lump sum payment.

Design and Engineering

Firth Stresscrete is New Zealand's largest manufacturer of precast prestressed concrete. The company has been designing and manufacturing prestressed concrete power poles in New Zealand since the early 1950s.

Computer aided designs for a range of different poles have been well proven in service and by load tests.

It was decided to adapt a standard tapered I-section pole to give a series of poles to suit the varying load and service conditions. Fig. 1 shows front and side elevations, cross section, design loadings and other details of a typical pole.

Each pole location is designed and detailed for its particular loads. The poles, cantilever arms and foundations are selected to provide the most economical solution for each location. Poles are manufactured to various lengths and strengths to cater for varying groundlevels and bending moments.

Twelve types of poles were eventually required. These were produced from five different molds. The five molds produced:

1. Long and short poles for straight track.
2. Long and short poles for curved track.
3. Extra long poles for steep foundation sites.
4. Crossing loop poles with cantilever arms on each side.
5. Poles to bolt on the sides of bridges.
6. Portal poles to support steel cross beams over several tracks in station areas.
7. Headspan poles to support multiple conductors off a suspended catenary wire for multiple tracks in marshalling yards.
8. Bolted base poles for use on pad footings.
9. Substation poles and overhead feeder poles.
10. Clearance poles to raise other power distribution lines above the main power feed wire.

All poles were designed to have compatible strand patterns using 12.5 mm (½ in.) diameter seven wire strand. This enabled them to be cast end to end on long line stressing beds.

The poles were designed and manufactured to New Zealand Standard NZS 3115 (1980) "Concrete Poles for Electrical Transmission and Distribution." This is a performance standard allowing any recognized concrete design method to be used but specifying cracking moments and ultimate capacity in terms of design working loads.

The standard specifies test loading procedures to destruction to prove the design and also load tests to working loads as part of the quality assurance procedure.

The design parameters set out in the standard are:

1. No cracks under working loads.
2. A factor of safety against collapse of 2.0.
3. A down line strength of 25 percent of the transverse strength.
4. Tip deflection under working load of 1/50 of the height above ground.
5. Minimum concrete cover to any

steel reinforcement of 20 mm (0.8 in.).

The only amendment to this standard was to reduce the allowable tip deflection to limit the deflection at conductor level to 50 mm (2 in.). This was done to ensure that the conductor wire would not be blown off the locomotive pantograph contact under maximum operating wind speeds.

Form Design and Pole Production

An essential item in reducing production costs is an efficient and durable form. Hinged steel forms were used that have required very little maintenance after the 700 casting days that they have been in production to date.

The poles are cured by circulating hot water through tubes built into the forms. Insulated fabric covers are used to minimize heat losses. The design 28-day cylinder strength of the poles is 45 MPa (6500 psi) and transfer strengths in excess of the 28 MPa (4000 psi) minimum are achieved after 16 hours of curing.

The factory producing the poles is also manufacturing poles for local power supply authorities, flooring products for buildings, and bridge beams. No special skills are called for in the production of the railroad poles and no additional mechanized equipment was required. The minimum equipment is one overhead crane to strip the poles from the molds and a forklift to stockpile the poles and to load the rail wagons. Production labor averages 3 to 4 man hours per pole and the poles are produced at a rate of 90 poles per week.

With each pole made for a specific track location, schedules of poles are given as soon as the pole location and design parameters are determined by the main contractor and the New Zealand Railways. A wagon loading sequence is also given for each wagon load of poles. This ensures that poles can be placed from the train in the correct sequence.

Fig. 2. Hi-Rail crane with auger attachment prepares to excavate a pole foundation.

Quality Assurance

Poles are manufactured to a rigid quality assurance program. This starts with the design of the product and the molds; includes quality control checks on the component materials, the production methods, the finished product, and transport and handling.

Part of the requirements of NZS 3115 requires one pole in every 100 to be test loaded up to the design working load. At this load it must have no cracks and its deflection must be within ±15 percent of the average deflection for all poles of that type tested.

The aim of the quality assurance program is to ensure that all poles leaving the factory are satisfactory. Remedial work at remote sites, often without road access, is very expensive.

Pole Installation

Installation of these poles through particularly rugged sections of the central North Island of New Zealand is hampered by lack of access. Often the only access is from the rail track. This is a single track and must be cleared for the passage of trains at regular times.

This problem has stretched the ingenuity of the McConnell Dowell — MCE joint venture and has led them to develop a novel series of dual road-rail and rail mounted machines. These machines are able to perform all the major pole installation functions and are quickly able to lift themselves clear of the track to enable trains to pass.

The installation starts with the passage of a supply train hauling wagon loads of poles. The poles are laid alongside the track by a hydraulic crane mounted on a rail wagon. Workmen then dress the poles with the insulators and stand-off tube, and fit any other special hardware. When the poles have been laid out, the foundation holes are augered by two rail mounted hydraulic cranes equipped with power swivels and pendulum augers (Fig. 2). A third rail mounted Palfinger crane (Fig. 3) follows the auger cranes and lifts the poles into position where they are temporarily braced in the correct alignment.

Fig. 3. Pole installation using rail mounted crane.

Concrete is delivered to the foundation holes by a hydraulically driven rail mounted truck transporter (Fig. 4). This transporter is capable of carrying a fully loaded ready-mixed concrete truck at speeds of up to 25 km per hour (15 miles per hour). This machine is also able to lift itself clear of the track onto transportable stands similar to those used by normal track maintenance machines. The concrete transporter has proven to be so ideal for the job that a further five machines have been sold for use on Australian railroads.

Fig. 5 shows the equipment used for running out the contact wire.

The conductors were installed using a rail mounted truck with a hydraulic lift

Fig. 4. Rail mounted concrete transporter for casting in place pole foundations.

Fig. 5. Equipment used for running out the contact wire.

platform, as shown in Fig. 6.

Fig. 7 shows the final adjustment of contact wire and the finished pole configuration.

Using the above specialized equipment, the joint venture's small highly motivated crew have been able to install poles at a rate of up to 150 poles per 5-day week.

The erection of the overhead conductors is split into three separate operations:

1. Running out and sagging of the fixed termination conductors.
2. Running out and tensioning of the counterweight tensioned contact

Fig. 6. Hi-Rail truck with hydraulic lift platform installing conductors.

and catenary system.

3. Registration to line and level of the contact and catenary wires and final adjustment to the cantilevers.

For each of these operations equipment has been developed using both road-rail vehicles and modified New Zealand Railways rolling stock.

Foundations

An economical method of overcoming varying ground levels and soil bearing capacities without the need to produce a wide range of different pole lengths was essential to reduce both the pole production costs and the cost of foundations.

Fig. 7. Final adjustment of contact wire showing finished pole configuration.

The solution arrived at, after extensive site testing, was able to accommodate the typical range of ground levels, and soils varying from poorly compacted embankment fill to well compacted soils and soft rock, using only two lengths of poles.

Concluding Remarks

The choice of an I-shaped section results in a pole that ideally matches the service loads. The pole is designed for the load of wind on the wires in the direction transverse to the track. In the opposite down line direction the load capacity of 25 percent of the transverse strength provides an adequate margin for handling loads, wire tensioning loads and accidental overloads.

By choosing a production method that is compatible with the normal range of products in a typical precast prestressed concrete factory, the system is economical for small production runs in factories that wish to diversify their product range.

The prestressed concrete poles for this railroad electrification project have won the New Zealand Concrete Society's 1986 Prestressed Concrete Award.

In making this award, the judges were impressed by both the structural efficiency of the design and the aesthetically pleasing appearance of the slender fluted poles. They were also impressed by the on-going commercial implications of the project. The design and manufacturing systems have been so successful that they have been licensed for use in other countries.

The use of these slender prestressed concrete poles has minimized the intrusion of the overhead electrification on the predominantly rural environment that the railroad passes through.

Stage I of this railroad electrification has been completed. Stage II is due to be completed by February 1988. The successful manufacture and installation over more than 8000 poles without a problem is a tribute to Firth Stresscrete's production personnel and to McConnell Dowell — MCE's field crews.

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NOTE: Discussion of this article is invited. Please submit your comments to PCI Headquarters by June 1, 1988.