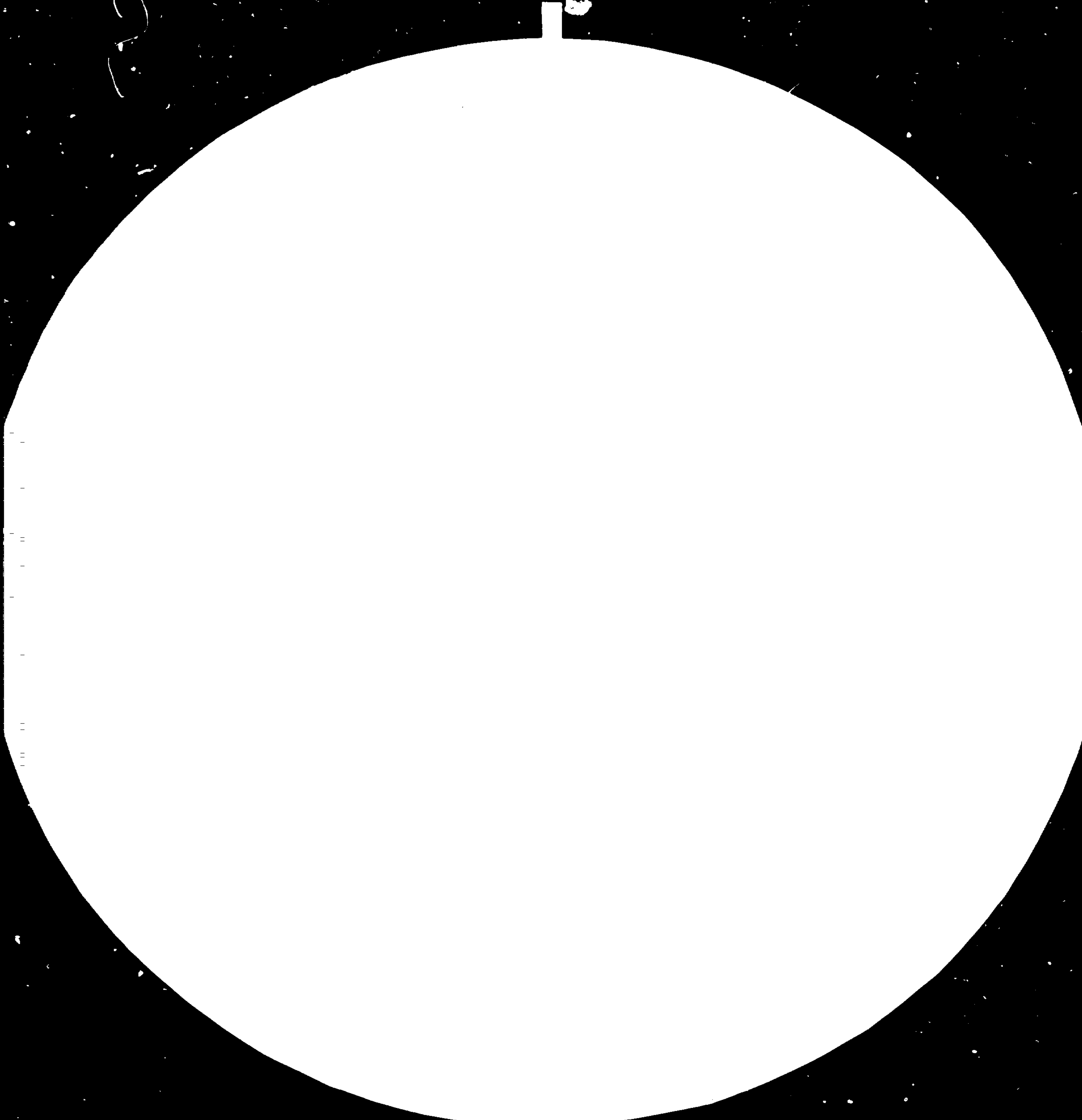

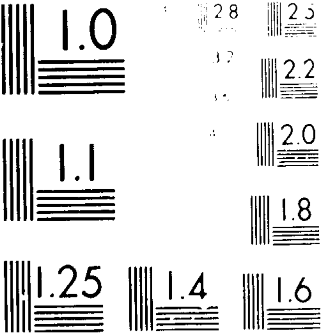

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Distr.
LIMITED

ID/WG.347/32
11 November 1981

ENGLISH

United Nations Industrial Development Organization

Workshop on Cement and Concrete Products
Brisbane, Australia, 18 - 29 May 1981

HOLLOW SPUN REINFORCED CONCRETE POLES*

by

P. Bainbridge**

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** Rocla Concrete Pipes Ltd.

V.81-32097

1. History and Development of Concrete Poles

The evolution of today's concrete pole has been a result of three things:

- Advances in pole making technology
- Advances in reinforcement technology
- Advances in concrete technology

1.1 Advances in Pole Making Technology

The first poles made were of rectangular section reinforced cast concrete, perhaps not unlike the early Australian concrete fence post but on a larger scale.

In some parts of the world this method, vastly improved admittedly, is still used to make poles.

After the early cast poles came the first of the spun poles. These poles were first used about 50 years ago in Europe and Japan. They were reinforced with a rather crude handmade reinforcing cage but, despite this, many of these are still in service today.

Today's spun poles with their extremely high concrete densities and precisely placed reinforcement (often prestressed) first appeared about 20 or 30 years ago. Hollow spun concrete poles are now used throughout the world in ever increasing numbers as available wood supplies dwindle.

1.2 Advance in Concrete Technology

Concrete has been with us since Roman times but the era of modern concrete did not commence until about 1824 with the patenting of a process to make Portland cement.

Reinforcing in concrete was used from as early as 1854 but the really big advances in concrete have come during this century.

The concrete in common use today has been vastly improved in the last 50 years. Improvements have arisen from introduction of better cement, from better knowledge of mix design, water/cement ratios, and better compaction.

The strengths of precast concrete today are about three times what they were 50 years ago. There has been a similar increase in concrete durability arising from dramatic reductions in concrete permeability.

1.3 Advances in Reinforcement Technology

The advances in reinforcement technology have come in the type and quality of reinforcing still available and in the accuracy of placement of that reinforcement.

As a rough guide the working stress of today's reinforcement is twice that being used 50 years ago.

2. Design of Concrete Poles

2.1 Reinforced Concrete Poles

2.1.1 The Development of Reinforced Concrete Poles

The first concrete poles were fairly crude cast rectangular section poles and the reinforcement also was far behind today's standard. When spun circular section concrete poles were first introduced the reinforcement cage was still made by hand and it was not until the early 60's that a machine was invented that could automatically weld a tapered pole reinforcing cage. This machine was invented by the engineering department of Rocla (Australia) and solved the problems of tapering cage, varying pitch spiral and increasing numbers of longitudinals in the cage. The machine has been refined to a point where it makes Rocla the world leader in reinforced concrete pole manufacturing techniques.

2.1.2 Advantages of Reinforced Poles

The main advantage of reinforced concrete pole manufacture, as manufactured by Rocla (Australia), is that the reinforcement cage is rigid and:

- can be welded to
- is the total pole reinforcement
- is easily positioned in the pole
- can be made automatically

and these things combine to enable efficient manufacture of the reinforcement and hence of reinforced concrete poles.

2.2 Prestressed Concrete Poles

There is no such thing as a prestressed concrete pole, rather there are poles which have composite reinforcing, i.e. both prestressed and non-prestressed reinforcement.

2.2.1 The Development of Prestressed Concrete Poles

Many people making spun reinforced concrete poles in the early days had severe problems arising simply from the fact that their reinforcement cage was being made by hand. It was thus both time consuming and costly to make and also being hand made it was not rigid and therefore hard to locate in the pole and prone to break up during pole spinning.

From this point there are two paths to a solution. The one taken by Rocla was to devise a method of making satisfactory reinforcement cages. The other was to find an alternative method of making concrete poles, this lead to the birth of prestressed concrete poles.

The first tapered prestressed concrete poles were made without any non-prestressed reinforcement and were quick and failrly cheap to make. Unfortunately, they were unsatisfactory because of very poor torsion and impact performances and comparatively poor bending capacity towards the pole base. To overcome these problems, non-prestressed reinforcement was added and this led to today's composite prestressed concrete pole. The percentage of prestressing wires is about 45% of the total steel.

2.2.2 Advantages of Prestressed Concrete Poles

The main advantage of prestressed concrete poles is for manufacturers who do not have an automatic cage making machine. They can use the prestressing wires as a frame for a relatively light hand made non-prestressed reinforcement cage and also use the prestressing wire to position the non-prestressed reinforcement cage in the pole.

From pole users point of view, prestressed concrete poles have the (questionable) advantage that crack width is slightly smaller than reinforced concrete poles under working load.

2.2.3 Disadvantages of Prestressed Concrete Poles

The main disadvantage of poles reinforced with a composite non-prestressed and prestressed cage (i.e. no rigid non-prestressed reinforcement cage) is that fittings and attachments are not as easy to attach. Fittings can be attached to a ridgid non-prestressed cage by welding or cutting but it is not possible to weld or to cut prestressing wire.

The cost of the reinforcement system in non-prestressed reinforced poles and composite prestressed poles is very similar. This is because although prestressing wire is more expensive than normal wire less of it is required as it has a higher tensile strength than normal wire.

A significant disadvantage with prestressed concrete poles is that their stripping time is double which leads to double the number of moulds.

2.3 Safety Factors

Safety factors for concrete poles are specified by the user authorities in the various states.

In Victoria where concrete poles have been used by the State Electricity Commission of Victoria, for a considerable number of years, the safety factor is 2.0, i.e. the guaranteed ultimate load of a concrete pole must be at least twice the working load specified by the State Electricity Commission.

Another common safety factor is 2.5 and generally this factor has its historical basis in the relevant British Standard BS 607 Part 2.

3. Manufacture of Concrete Poles

3.1 Reinforced Concrete Poles

3.1.1 Wire Straightening

The reinforcing steel is hard drawn plain wire and is delivered from the steel mills in coils. It is straightened in a machine as it passes through offset rotating dyes. This wire straightener also custs the straightened wire for use in the reinforcement making machine.

3.1.2 Reinforcement Manufacture

The straightened wire is loaded into the cage making machine in a predetermined pattern.

The reinforcement is formed by electric resistance welding a spiral around the longitudinals as they are drawn out of the machine.

3.1.3 Secondary Welding

The reinforcement cage from the reinforcement making machine is now trimmed to length and the fittings are added.

Fittings are attached by arc welding to the reinforcing cage.

Fittings are specified by the user authorities and range from galvanised pole caps to simple holes and threaded ferrules for step bolts and earthing. Blockouts for openings and doors are also easily provided.

3.1.4 Reinforcement Studding

Studding ensures that cages are located in precisely the right position in the concrete pole. Studs are stainless steel and applied using the Rocla developed studding gun. The weld is so strong that studs cannot be knocked off the completed reinforcement.

3.1.5 Concrete Placing

Concrete is placed, after mixing, from a motorised hopper into the bottom section (containing the reinforcement) of the two piece mould. The concrete is carefully distributed and the mould bolted up.

3.1.6 Spinning

The mould is spun on a trunnion spinner to a predetermined program of time and speed depending on the pole type and size.

Spinning normally takes about 20 minutes and trunnion speed is about 1500 rpm

3.1.7 Curing

After spinning the pole is given accelerated hardening by steam curing. This enables stripping of the pole three to four hours after concrete mixing. This high mould utilisation is essential for economical pole production.

When the pole is stripped it is finished off, holes cleaned out, etc., on benches prior to stacking in the yard. The pole is now stacked in the yard and air aged a further minimum of seven days before despatch.

Yard handling is always done with two point lifting but by the time of despatch the poles are strong enough for a single point lift.

3.2 Prestressed Concrete Poles

3.2.1 High Tensile Wire Preparation

Prestressing wire needs no straightening as it is so springy it uncoils straight.

To prepare prestressing longitudinals they are cut to length and buttonheaded to very precise tolerances on length. This is required because the pretension in the wire is achieved by extending the wire a certain distance and should wire vary in original length then final pretension will vary - a disastrous situation.

3.2.2 Non-Prestressed Cage Preparation

The non-prestressed cage is normally made by hand and twitched together. It is not rigid and could not be used alone to reinforce a pole, so must be used always in conjunction th prestressing wire.

3.2.3 Mould Preparation

As fittings cannot be attached to the cage as with reinforced poles they must be attached in an alternative manner, i.e. it is not possible to weld to high tensile prestressing wire.

This is done by standardising on fittings for poles and attaching those fittings by casting into the concrete. During spinning and concrete hardening the fittings are attached securely to the mould and only released immediately prior to stripping.

3.2.4 Concrete Placing

There are two methods of stressing and these control how concrete is placed.

3.2.4.1 Stressing Prior to Concrete Placing

If stressing is done prior to placing then concrete must be placed with the mould closed and bolted up.

There are a number of ways of doing this; two common methods are:

i) Mould Angled

The stressed mould is tilted at about 30° and slowly rotated, as rotation proceeds a prebatched volume of concrete is dribbled slowly in from the higher end.

This is an extremely slow process and mould filling is not always even.

ii) Concrete Pumping

In this method a long tube is inserted into the stressed mould and as it is withdrawn pumps a prebatched volume of concrete into the mould. This is fast but expensive and presently limited to about a maximum of 18 metre poles.

3.2.5 Spinning

The spinning process is identical to that for reinforced concrete poles.

3.2.6 Curing

Curing prestressed poles takes twice as long as reinforced poles because relatively high concrete strengths must be achieved before the prestress can be transferred from the mould to the concrete.

Apart from the time difference and the prestress transfer curing is the same for both pole types.

3.2.7 Secondary Curing

Once the prestressed pole has been stripped it is stacked in the yard and air cured for a further seven days before despatch - in a similar manner to reinforced poles.

4. Testing of Concrete Poles

4.1 Types of Tests

The testing of poles is usually specified by the purchaser and adheres to a format and schedule specified by them. As an example the testing requirements of the SECV can be examined.

4.1.1 Proof Test

This is a test done to prove a new design and before it is done no poles of that size and strength are able to be despatched.

The test increases the lateral and torsional load on the pole incrementally until the ultimate load (twice the working load) is reached. The pole is then further loaded until failure of the pole and the failure type is recorded.

The lateral and angular deflection of poles are recorded at specified loads to be used as reference points for batch tests.

4.1.2 Batch Test

Once a pole has been proof tested and a production run of poles commenced, one pole is selected from every batch of specified size to be batch tested.

This batch test requires that at the lateral and torsional working loads the pole deflection be within a set percentage of the deflection recorded at that load during the proof tests.

4.2 Deflection vs Load

The deflection of concrete poles naturally depends on the pole length and strength and the load applied.

The deflection both laterally and angullarly is significantly less than would occur on testing of a similar size and strength wood pole.

The attached table illustrates the difference for 11 metre 8 kn poles.

4.3 Failure Types

There are three basic types of failure when ultimate testing poles. Often failure during testing is a combination of types.

4.3.1 Concrete Compression Failure

This failure type normally occurs at the simulated groundline point in a test and occurs when the concrete on the compression face of the pole crushes.

4.3.2 Steel Tensile Failure

This failure type also normally occurs at the simulated groundline point in a test and occurs when the steel on the tension face of the pole necks and breaks.

4.3.3 Concrete Tensile Failure (Torsion)

This type of failure, during ultimate testing, occurs at the head of a pole that has a small tip diameter and a relatively large torsional load when compared with its load rating. This failure type is nearly always limited to lighting poles.

It is characterised by diagonal (45°) cracks and by concrete spalling or sheeting away from the reinforcing cage.

4.3.4 Comparing Testing of Prestressed and Reinforced Concrete Poles

The tests, failure types and performance of these two types of poles is nearly identical. The only slight difference is that prestressed concrete poles deflect marginally more than reinforced poles.

*DEFLECTION COMPARISON : WOOD/CONCRETE

% of Ultimate	Load KN	Wood Deflection		(Test 86) Concrete 1 Deflection		(Test 85) Concrete 2 Deflection		(Test 84) Concrete 3 Deflection	
		Lateral	Angular	Lateral	Angular	Lateral	Angular	Lateral	Angular
0	0.0	0	0	0	0	0	0	0	0
10	1.6	90	1	19	0	19	0	16	0
20	3.2	200	1 3/4	90	0	54	0	59	0
30	4.8	320	2 1/2	132	0	137	0	134	0
40	6.4	430	3 1/4	236	0	226	0	214	0
50	8.0	543	4	353	½	327	½	330	½

*NB All poles 11 metre - 8 Kn