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Surface Foundations for Emergency Poles

Load Testing of Initial Designs

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Paper Abstract

As part of Wellington Electricity Lines Ltd's (Wellington Electricity) ongoing work to provide cost effective risk based solutions to High Impact Low Probability (HILP) events, this paper provides an update of work between Wellington Electricity and LineTech to develop an emergency overhead lines system as a contingency plan to bypass any 33kV underground cables damaged during a major earthquake.

The concept envisaged was a set of pre-planned and fully designed emergency overhead routes between key substations, connected with overhead lines built with concrete poles.

Because the emergency line routes run in part across public parks, along paved streets etc, a system of surface mount pole foundations was envisaged to avoid excavating and damaging existing underground services, and speeding up construction of the line.

Staying of poles is not practical or desirable in many locations so a heavy duty foundation option is needed. The surface foundations will enable poles to be placed almost anywhere. The foundations will be made of steel and weighted down with concrete anchor blocks.

Prototypes of both these foundations have been manufactured. As they are completely new and untested designs, physical load testing is needed to check if the designs would work as intended.

This paper sets out the results and lessons learned from the first round of prototype load testing on both the large and small foundation, carried out in Oct 2015 and summarises the plan to complete the emergency overhead lines system.

Surface Foundations for Emergency Poles
Load Testing of Initial Designs

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1.0 BACKGROUND

In 2011 a design process was initiated between LineTech and Wellington Electricity to develop an emergency overhead lines “system” to bypass any underground cables which may fail unexpectedly in service, or for example during an earthquake. The concept envisaged was a set of pre-planned and fully designed emergency overhead routes between key substations, connected with overhead 33kV lines built with concrete poles.

Because the emergency line routes ran across public parks, down paved streets across sealed carparks etc (including for example down “The Terrace”), a system of surface mount pole foundations was planned to avoid excavating and damaging existing underground services, and speeding construction of the line. Also because staying of poles would not be possible or would be undesirable in many locations, a heavy duty foundation option was needed. The surface foundations would enable poles to be placed almost anywhere. The foundations would be made of steel and weighted down with concrete anchor blocks.

Subsequent progress has seen the completion of eight emergency line routes and two surface foundations have been designed and incorporated into these routes- a light and a heavy duty foundation.

Prototypes of both these foundations have been manufactured by Ashhurst Engineering. As they are completely new and untested designs, physical load testing was needed to test if the designs would work as intended.

This report sets out the results and lessons learned from the first round of prototype testing.

2.0 THE TWO FOUNDATION DESIGNS

There are currently two foundation designs – light and heavy duty. Both foundations are made of galvanised box section steel and use concrete anchor blocks to weigh them down. Adjustable clamps are used to grip the pole that is mounted in the foundation.

The light foundation is designed for in-line poles with short spans, and no turnoff angles. Its base measures 2m x 2m giving a maximum top load (on a 12.4m concrete pole) of 4.5 kN using four concrete anchor blocks.

An overview drawing of this foundation is set out in **Attachment 1.**

The heavy duty foundation has been designed for longer spans, twin circuit poles, and poles supporting unguyed turn-off angles and dead ends. It measures 4.16 m x 2.36 m. This foundation is designed for a top load of 35kN on a 12.4m concrete pole and uses up to 8 concrete anchor blocks.

The heavy duty foundation therefore has a transverse load capacity of approximately 8 times that of the light duty foundation, and has a maximum pole top load of nearly 3.6 tonne. Both foundations were designed to cope with a range of sizes of concrete and timber poles.

An overview drawing of this foundation is set out in **Attachment 2.**

3.0 THE TEST SYSTEM

A contract was let to Ashhurst Engineering to undertake the foundation testing.

A test procedure was developed by LineTech and Ashhurst Engineering involving two truck cranes. One crane was used to lift the poles into the foundation, and also to apply the horizontal transverse loads to the poles at 12.4m above the ground. A second crane was used to apply the smaller longitudinal (or in-line) loads.

A cherry picker was used to access the pole top and attach and disconnect load strops. A forklift was used to place and remove the concrete blocks. Digital remote reading dynameters were used to monitor applied loads.

The testing was carried out in October 2015. The light duty foundation was tested first followed by the heavy duty foundation. The test procedure involved a number of increasing load tests for each foundation with different numbers and arrangements of anchor blocks, up to the maximum design working loads. Test loads were increased until either the foundation began to lift (tip), something on the foundation began to deform or fail, or the test load was reached.

A Busck 12.4m 43kN concrete pole was used for all the tests as this is the strongest concrete pole available thus minimising the risk of a pole failure during testing. The pole weighed 2.3 tonnes. The concrete anchor blocks used were 900 x 870 x 870 mm in dimensions and weighed 1670kg each.

4.0 TESTING OF THE LIGHT DUTY FOUNDATION

4.1 The Tests

The planned and actual test loads for the light duty foundation are set out in Table 1.

Table 1: Light Duty Surface Foundation Loading Tests

Test	**Block Pattern**		**Design or Test load**	**Max Top Load kg**		**Result**
#	**Left**	**Right**		**Longitudinal**	**Transverse**	
1	1		Design	280	280	Passed
		1	Achieved	314	300	
2	1		Design	NA	370	Passed
	1		Achieved		380	
3	1		Design	NA	400	Passed
	1	1	Achieved		430	
4	1	1	Design	NA	459	Passed (3)
	1	1	Achieved		550 peak	

Notes:

1. *Longitudinal testing was stopped after test 1 as the pole was bending noticeably due the load being in its weakest direction.*
2. *After test 2 the upper pole clamps had racked slightly, and this got progressively worse after test 3 and 4.*
3. *Test 4 was peaked at 550kg momentarily to see if the foundation would tip over (it didn't) before backing off to 459kg.*

4.2 Comments

At peak load on test # 4, the foundation frame outer (lifting) edge had lifted off the ground approximately 10 mm. However the centre of the frame remained on the ground and the foundation did not show signs of tipping over.

The foundation passed its test loads without apparent difficulty, other than some "racking" distortion of the upper clamping bolts. **(Attachment 3, Photo 3.)** After the loads were removed and the clamps released, the bolts returned to their original straight condition and so did not suffer any permanent deformation.

No other component on this foundation suffered any damage or distortion during the testing. The anchor blocks were not restrained on the foundation and did not move or fall off under the test loads.

5.0 TESTING OF THE HEAVY DUTY FOUNDATION

5.1 The Tests

The planned and actual test loads for the heavy duty foundation are set out in Table 2 below.

Table 2: Heavy Duty Surface Foundation Loading Tests

Test #	Block Pattern Left	Block Pattern Right	Design or Test load	Max Top Load kg Longitudinal	Max Top Load kg Transverse	Result
1	1		Design	250	1160	Notes 1 & 2
		1	Achieved	252	930	
2	1		Design	NA	1794	Notes 2 & 3
	1		Achieved		1352	
3	1	1	Design	NA	1978	Note 4
	1	1	Achieved			
4	2		Design	NA	3201	Note 4
	2		Achieved			
5	2	1	Design	NA	3385	Note 4
	2	1	Achieved			
6	2	2	Design	NA	3579	Note 4
	2	2	Achieved			

Notes:

1. *Longitudinal testing was stopped after test 1 as the pole was bending noticeably due the load being in its weakest direction.*
2. *Outer edge of the frame was lifting slightly. Centre section remained on the ground.*

3 *After test 2 the upper pole clamps had racked significantly and the pole had lifted in the frame by approximately 25 mm.*
4. *Tests not conducted due to risk of the pole butt rising right out of the lower frame clamps and/or the upper pole clamp bolts shearing due to differential movement. Both issues would have resulted in the pole falling and creating a safety hazard.*

5.2 Comments

The inability of the pole clamping system to cope with the taper on the base of the Busck concrete pole resulted in the testing having to be stopped after test 2. Two key problems occurred:

a) The butt clamping system, while very firmly clamping the pole was unable to prevent the pole riding up the taper when the poles were under load.

b) The upper clamping system was also struggling to cope with the combination of the pole base taper and the tendency for the compression clamps to ride up the pole and the uplift clamps to ride down, under pole load.

The combination of these problems resulted in the two pairs of clamps moving differentially and racking or S bending the clamping bolts and allowing the butt of the pole to move upwards out of the base clamps. (See **Attachment 3, photos 5 and 6**)

6.0 DESIGN PROBLEMS AND TENTATIVE FIXES

6.1 Frames

Overall the foundation frames performed as expected under the applied loads. Some deflection occurred under load and was to be expected. No permanent deformations or weld failures occurred. Once the clamping problems are resolved for the heavy duty foundation, and full design loads can be applied, the stiffness of this frame can be further evaluated under full load conditions.

6.2 Butt clamps

The butt clamping system on the light duty foundation utilises a Busck concrete base donut. The concrete pole butt wedged tightly into this base and did not suffer from the same problems as the larger foundation. (However the loads applied to this foundation were small compared with the heavy duty foundation). The clamping system on the light duty foundation was also very easy and quick to adjust. Further, the full pole weight reliably bears on the foundation thus increasing its overturning moment.

The heavy duty foundation (an earlier design) uses a more complex system of beams and adjustable clamps to set the pole to vertical and to bear tightly on any pole shape and size. (**Attachment 3, Photo 5**) This process is needed for any site in which the frame is not set horizontal (e.g. in a sloping street). However the weight and complexity of the components and the number of bolt hole combinations required meant that over 30 minutes was spent on the day of the testing to try to get the pole clamped tightly so when the foundation lifted (tilted) under test, the full pole weight would be picked up maximising the overturning moment.

A redesign of the butt clamping on the heavy duty foundation is needed to improve and simplify the design, and also lower the cost of the foundation fabrication. This could perhaps incorporate aspects of the light duty foundation design but be beefed up to take the heavier loads.

6.3 Upper pole clamps

Both foundations suffered from the same problem in which the transverse loads forced the upper pole support clamps to move differentially up and down the pole taper, racking or "S bending the attachment bolts. **(Attachment 3, Photos 3 and 6)**

A redesign of the clamps which perhaps involves interlocking the upper attachment system into a single unit which cannot move differentially may prevent this problem.

A number of other design options are also possible available including vertical tie rods to anchor the clamp positions in uplift.

6.4 Strut Positioning on the Heavy Duty foundation.

The greatest loads applied to the heavy duty foundation are the compression transverse loads across the widest face of the foundation. Currently these compression loads are shared by two struts attaching only part way up the foundation section of the pole (**Attachment 2**). Because the upper clamps are positioned well down the pole foundation section, significant loads are being applied below the normal design ground line position.

By rotating the strut mounting positions 90 deg on the foundation, the transverse face struts move outwards approximately 1m on each side. If they maintain approximately the current rake angle this means that the poles can be gripped much higher above ground, and closer to the correct pole ground line position. Further, at this location the upper pole clamps can be locked around the section angle change and this help may prevent the clamps riding up and down the pole.

7.0 PROPOSED FUTURE WORK

7.1 Redesign the upper clamping of both foundations to prevent differential movement.

7.2 Redesign the pole butt clamping system on the heavy duty foundation perhaps along the lines of the light duty design.

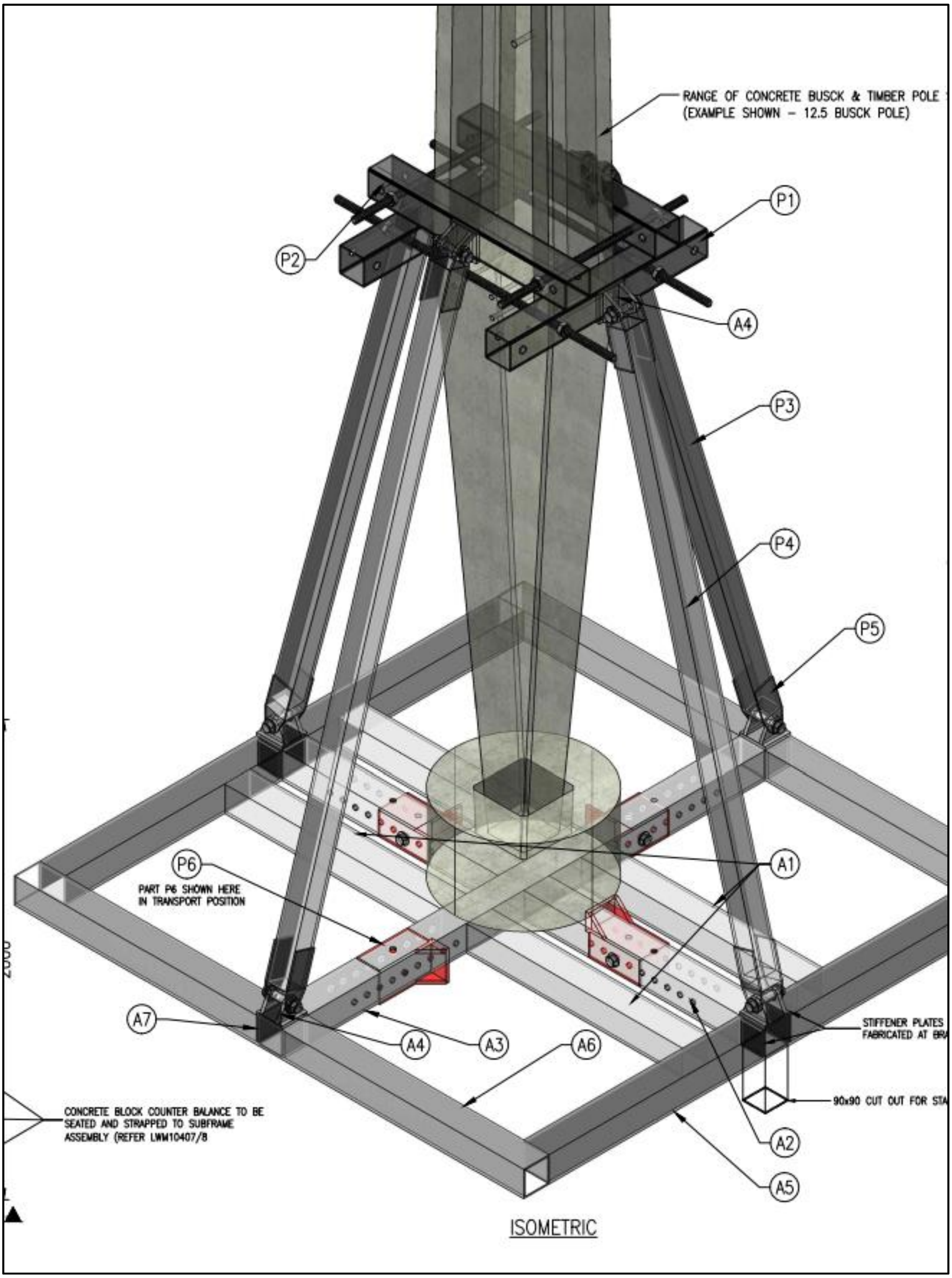
7.3 Review the design of the strut positioning on the heavy duty foundation to increase the upper clamping height nearer to the nominal pole ground line.

7.4 On completion of the redesign work, modify both of the prototype foundations to incorporate the new design features.

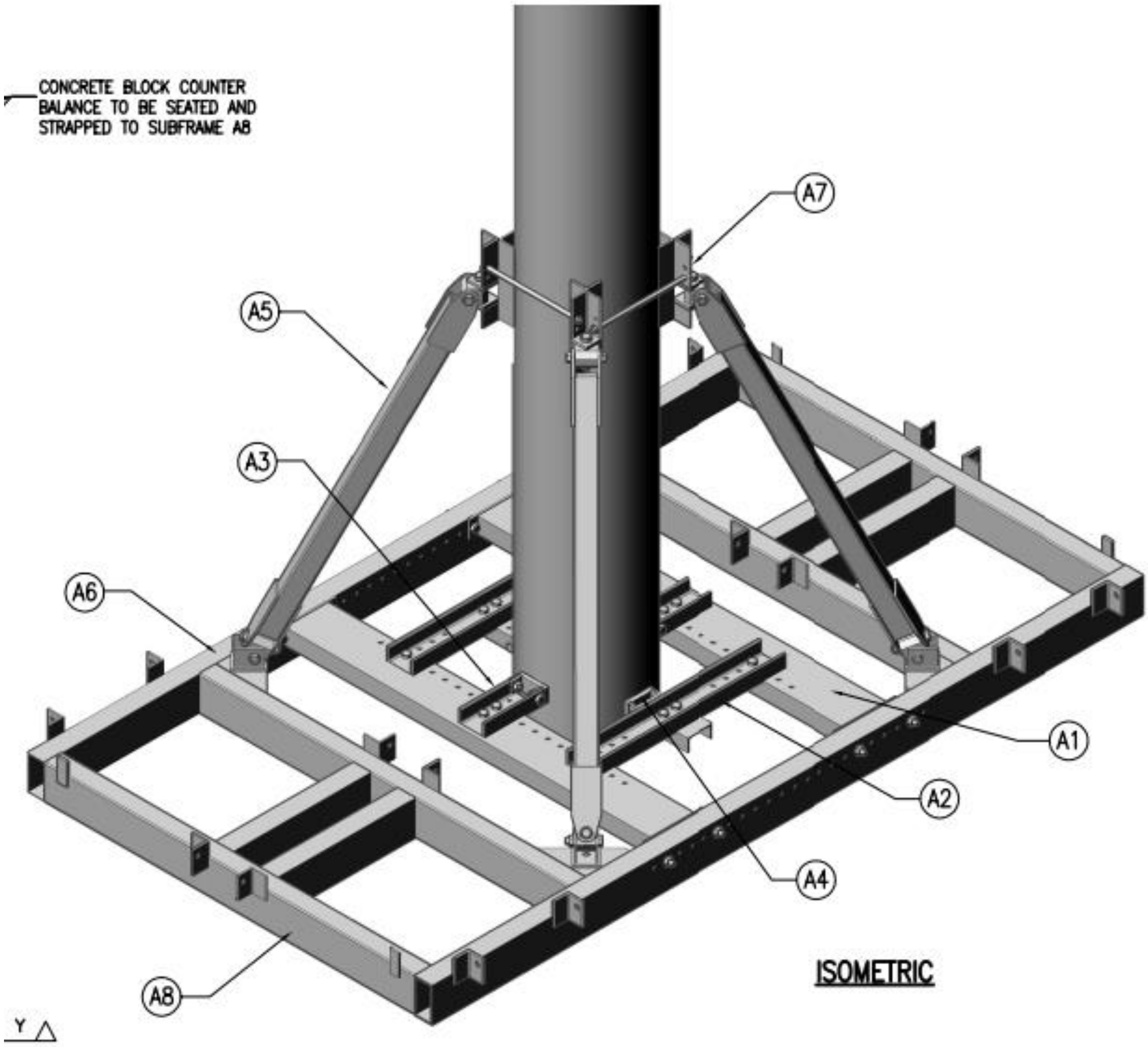
7.5 On completion of modifications, load test both foundations to check their re performance.

The above work is planned for completion during the current calendar year (2016).

Attachment 1: Light Duty Foundation



Attachment 2: Heavy Duty Foundation.



Attachment 3: Photographs

Photo 1: Heavy and light duty foundations side by side before testing. The concrete anchor blocks and test pole are in the background.

Photo 2: Light foundation under load test 3. (Three blocks)

Photo 3: Light foundation pole lower section after test 4. Note the “S” bend in the clamping**.**

Photo 4: Heavy duty foundation under load test 1 (two diagonal blocks)

Photo 5: Heavy duty foundation butt clamping showing upward movement under test load 2

Photo 6: Heavy duty foundation upper clamping after test 2, showing differential vertical movement of clamps along the pole face.