Services Report

Job no: T3160

Title: Testing and Evaluation of Perma-Soil, Soil Stabiliser

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Summary:

EA Technology has conducted a number of tests associated with the Perma-Soil stabilisation method. Specifically the tests have been associated with the degree of mechanical resistivity provided by the surrounding area of the wood pole foundation of a distribution overhead line structure.

The testing was carried out at the Vertex Training and Developments Centre in Chorley using experienced overhead linesmen and technical support provided by EA Technology and Perma-Soil UK Ltd.

Analysis of the test results have found that improvement in the foundation strength can be provided when using the Perma-Soil treatment. This is specifically evident on structures where no blocks or baulks are fitted. Perma-Soil treated ground will generally increase the foundation capability. This may therefore allow single pole structures in areas of 'Average/Poor' soil conditions to be installed without the need to move directly to blocked structures, as the Perma-Soil system can improve the ground moment of resistance to that of 'Good' soil conditions.

Approved by: ....
D T Hughes
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Date: 11 February 2000

1 Introduction

EA Technology was recently approached by representatives of Perma-Soil UK in relation to the possibilities of work associated with the evaluation of the Perma-Soil Stabiliser. The following details the work that has been carried in order to fulfil this request.

Perma-Soil soil stabiliser has been used in the UK by a number of Regional Electricity Companies (RECs) over the past few years. The specific advantage that is claimed with its use is its ability to strengthen an overhead lines support at ground level.

The industry has recognised that the Perma-Soil system may be beneficial to the installation of structures and stays for overhead line construction. Both Perma-Soil UK and their customers are therefore interested in carrying out independent tests to evaluate the product in an engineered and controlled manner.

2 Scope

The principal aim of this project is to evaluate the samples provided and establish its suitability for use in a number of different ground condition service environments. In addition the views of EA Technology will be provided detailing the specific areas that need to be addressed in relation to the application and viability of the product for the UK and European market.

The project will initially demonstrate the performance of these systems in a number of service environments. Field tests have been carried out in which the results have been extrapolated and reported. These evaluations will provide a level comparison for the performance under typical UK distribution operating conditions.

3 Wood Pole Foundations

An overhead line foundations main requirement is to provide an effective restraint to loads which may be transmitted to it by the support. Ideally the foundation should be matched to the ultimate capability of the support so that the design of the line is limited by the support capability and not its foundation. At the same time a certain flexibility under loads sufficiently extreme to threaten the integrity of the support is desirable. These two requirements are difficult to meet simultaneously particularly given the very variable nature of the characteristics of the ground in which the supports are installed. Generally due to the surrounding backfill and soil classification the limiting criteria between the support’s strength and the foundation capability is indeed the foundation.

Stays or guys are generally introduced to help stabilise the structure from the horizontal loads produced by the conductors. These loads will naturally be more extreme depending on the angle of deviation that the support has to withstand. Applied loads will also increase on the support due to adverse weather conditions such as wind or ice acting directly on the conductors. The stresses produced are transferred to the pole top and in order to provide addition stability to the structure a stay is generally introduced to balance the horizontal pulling motion. The forces are then transferred into a vertical (strut) load acting on the structure. Depending on how severe the loads are acting on the structure will depend on the grade/class of structure used. Stays are certainly a problem or nuisance for wayleaves and maintenance reasons and where possible overhead line engineers would prefer to avoid their usage as small deviation points such as pin angles. The test associated with the Perma-Soil product are specifically aimed at those structures which have no additional means of support such as stays.

It is true to say that the countryside is littered with poles/structures leaning at angles from the true vertical or plumb line. It is therefore essential that a line design, which is to carry an important electrical load from one point to another, should not be allowed to fall down due to inadequate consideration given to structural stability.

The resistance to overturning a pole structure is a linear relationship to the diameter of the pole. Planting a pole deeper just increases the resistance to overturning relative to depth, but it is still a linear relationship to the pole diameter.

The strength of the pole is related to the cube of the diameter. Pole sizes selected for smaller conductors and shorter spans will have an overturning resistance generally higher than the strength of the pole, if we assume that the design of the line takes into consideration the prevailing ground conditions. If such ground conditions are ignored there is always the risk that the foundations would yield and the pole move out of line. Should this occur additional loadings are then placed on adjacent supports.

The basis of all good construction is the foundation and it must be capable of supporting the pole under all circumstances within the design parameters of the line.

3.1 Principles of Foundation Calculation

In order to calculate what forces the foundation must withstand it is important to know the resitivity or holding strength of the soil that the pole is to be planted in. It is known that a pole will pivot about a point below ground level. There are two formulae, one representing the parabolic form of stress distribution with the fulcrum point taken at $\frac{2h}{3}$ from ground level:-

$$\mathbf{Mg = \frac{k\,D\,h^3}{12}\ N\,m}$$

and the formula representing the straight line form of stress distribution where the fulcrum is taken as $\frac{h}{\sqrt{2}}$

$$\mathbf{Mg = \frac{k\,D\,h^3}{10}\ N\,m}$$

Where **D** = the average diameter of the pole below ground level in m
h = depth of planting in m
k = max. rupturing intensity in $N/m^2/m$ depth
Mg = moment of resistance of ground in N m

A straight-line formula is the one generally adopted by most overhead line design engineers. A maximum rupture intensity of stress is assumed which is directly proportional to the depth. In the following calculation '**k**' is taken to be 314175 $N/m^2/m$ (2000 1bs/sqft/ft)

The moment of resistance of the soil is the capability of that soil to resist the overturning moment of the wood pole.

Example 1

Pole planting depth = 1.5 m
Pole diameter = 0.3 m

$$\text{Moment of resistance} = \frac{314175 \times 0.3 \times 1.5^3}{10} \text{ N m}$$

$$\mathbf{= 31810 \text{ N m}}$$

For a pole let the wind load due to conductors be 5000 N. The load is applied at a distance above the fulcrum of 10.5 m + h/√2 m

Distance applied load to fulcrum	= 10.5 + 1.5/1.06 m = 11.91 m
Moment of force due to the conductors	= 59575 N m
Let the windage moment due to the pole	= 600 N m
Total overturning moment	**= 65575 N m**

In order that the foundation is adequate and can resist the total overturning moment it is necessary to increase the planting depth of the pole until the ground resistance is greater than the overturning moment. This however may not be the preferred solution and an alternative is to fit one or more baulks/blocks.

Normally if only one baulk is fitted, it is fitted 500 mm below the ground level. This is a compromise depth between maximum mechanical advantage and the minimum cover to allow farmers to plough over the baulk.

The standard size of baulk is 1300 x 250 x 125 mm
The area of baulk to resist overturning is 1.3 x 0.25 = 0.325 m^2
The area of the pole covered by the baulk is 0.3 x 0.25 = 0.075 m^2
The area of the baulk available for reinforcement is = 0.25 m^2

Taking moments about the fulcrum.

$$314175 \times 0.25 \times (1.5/\sqrt{2} - 0.5) \text{ N m } \mathbf{= 44036 \text{ N m}}$$

This added to the pole resistance of **31810 N m** gives a total of **75846 N m** therefore the resistance to the overturning moment is greater and would therefore be seen as acceptable as it exceeds the overturning moment of **65575 N M**.

It can be seen that there are primarily two ways in which the mechanical resistivity to pole movement can be increased;

(i) Increase the area of the support below ground level
(ii) Improve the resistive nature of the backfill so that the pole finds it harder to move.

Imported backfill has been used from time to time to assist with the latter of the two systems listed above. This is however an expensive method of improving the foundation capability. The Perma-Soil system provides an alternative means of improving the stability of the foundation, this is achieved by mixing the Perma-Soil solution in with the surrounding backfill and thus increasing the resistance due to its particular bonding properties.

4 Simulation and Testing

The following tests were carried out in association with Vertex Training Centre using experienced linesmen and training instructors. All test were carried out under the direct observation of a representative from Perma-Soil UK Ltd. The Vertex Training Centre based in Chorley provide training and development services for overhead linesmen and other disciplines associated with utility work.

Four wooden poles fabricated to the requirements of BS 1990 were installed at a suitable location within Vertex Training Centre complex. Four different foundation configurations would be used for the tests utilising two forms of backfill, eight tests in all. The following text details the configurations considered, the test results found and an analysis of the data produced.

Additional tests were carried out on the electrical resistivity of the foundations in the immediate area of the foundations as detailed in Appendix 2. These test are completely separate from the strength tests and were fundamentally carried out to establish if any improved electrical resistance in the ground could be attained through the use of the Perma-Soil system.

4.1 Pole Installations

The wood pole installations were carried out on three occasions prior to testing. The information detailed in this section 4.1 has been provided by Mr Derek Edwards of Perma-Soil UK Ltd. Mr Edwards observed each of the installations in turn and helped supervise the work associated with the preparation and foundation backfill using the Perma-Soil product.

EA Technology - Vertex, Perma-Soil Installation of Overhead Line Poles

Week Commencing 13 December 1999

Ground Conditions, Good Ground but wet due to excessive rain.

Four pole positions and central pulling point marked out. Clegg readings could not be achieved at any of the pole positions as Clegg Meter would not register drops due to soft/wet ground conditions.

Pole 1, Standard Pole erected in Perma-Soil treated soil

Excavation dimensions, 1.5 metres deep, 0.6 metres wide, 1.3 metres long (across pull). 25kg of Perma-Soil was added to soil during excavation. It is recommended that Perma-Soil be added at a ration of 25kg to 50kg per cubic metre of excavated earth depending on the moisture content.

Clegg reading at bottom of excavation, 3 on 4th drop and 4 on 5th drop.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and hand tamper in lifts of approximately 300 mm.

Compaction was good as the Perma-Soil had dried the soil. Clegg readings of 6 on 4th drop and 7 on 5th drop were achieved immediately after reinstatement, these had increased to 8 on 4th drop and 9 and 5th drop after 24 hours and 16 on 4th and 5th drop after 48 hours.

Pole 2, Standard Pole erected in excavated soil

Excavation dimensions, 1.5 metres deep, 0.6 metres wide, 1.3 metres long (across pull).

Clegg reading at bottom of excavation, 10 on 4th drop and 12 on 5th drop.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and hand tamper in lifts of approximately 300mm.

Compaction was difficult due to the wet ground conditions. No Clegg reading could be achieved after reinstatement of excavation as meter would not register drops.

Pole 3, Standard Pole with one standard block attached, non treated soil

Excavation dimensions, 1.5 metres deep, 0.6 metres wide, 1.5 metres long (across pull).

Clegg reading at bottom of excavation, 4 on 4th drop and 5 on 5th drop.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and hand tamper in lifts of approximately 300mm.
Compaction was difficult due to the wet ground conditions. No Clegg reading could be achieved after reinstatement of excavation at meter would not register drops.

Excess spoil was placed around base of pole.

Pole 4, Standard Pole with two standard blocks attached, non treated soil

Excavation dimensions, 1.5 metres deep, 0.7 metres wide, 1.5 metres long (across pull).

Clegg reading at bottom of excavation, 10 on 4th drop and 8 on 5th drop.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and hand tamper in lifts of approximately 300mm.

Compaction was difficult due to the wet ground conditions. No Clegg reading could be achieved after reinstatement of excavation as meter would not register drops.

Excess spoil was placed around base of pole.

Monday 20 December 1999

Ground conditions, good ground but wet due to excessive rain. No Clegg reading could be obtained prior to either of the augured installations due to damp ground conditions, meter would not register drops.

Pole 5, Standard Pole erected in Augured Hole

18” Augured hole to a depth of 1.5 metres

Pole was erected and compaction was achieved using a half moon hydraulic tamper in lifts of approximately 300 mm.

Clegg reading at base of pole prior to pull, 6 on 4th drop and 5 on 5th drop.

Pole 6, Standard Pole erected in Augured Hole, Treated with Perma-Soil

18” Augured hole to a depth of 1.5 metres. A problem was encountered during auger operation, at a dept of about 0.8 metres an obstacle (large rock) was encountered causing the auger to shift to one side. The result was an egg shaped hole with more spoil than pole 5.

13 kilograms of Perma-Soil was added to excavated soil during the auguring operation.

The pole was erected and compaction was achieved using a half moon hydraulic tamper in lifts of approximately 300mm as with pole 5.

Clegg reading at base of pole prior to pull, 16 on 4th drop and 17 on 5th drop.

Friday 7 January 2000

Ground conditions, good ground but wet due to excessive rain. No Clegg reading could be obtained prior to either of the installations due to damp ground conditions, meter would not register drops.

Pole 7, Standard Pole with one standard block attached, treated soil

Excavation dimensions, 1.5 metres deep, 0.6 metres wide, 1.5 metres long (across pull). 25kg of Perma-Soil was added to soil during excavation. It is recommended that Perma-Soil be added at a ratio of 25kg per cubic metre of excavated earth depending on the moisture content.

Clegg reading at bottom of excavation, 3 on 4th drop and 5 on 5th drop.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and tamper in lifts of approximately 300mm.

Clegg reading on installation, 9 on 4th drop and 10 on 5th drop.
Clegg reading prior to pull, 16 on 4th and 5th drops.

Pole 8, Standard Pole with two standard blocks attached, treated soil

Excavation dimensions, 1.5 metres deep, 0.7 to 0.9 metres wide in places, 1.5 metres long (final pull was at a slight angle to blocks).

Ground conditions for this excavation seemed a lot looser as the sides of the excavation kept falling in. No Clegg reading was taken at bottom of excavation due to danger of walls of excavation collapsing in.

30kg of Perma-Soil was added to soil during excavation.

Pole was erected and compaction was achieved using a combination of a petrol rammer (wacker) and tamper in lifts of approximately 300mm.

Clegg reading on installation, 5 on 4th drop and 6 on 5th drop.
Clegg reading prior to pull, 16 on 4th drop and 15 on 5th drop.

4.2 Pole Base Foundation Test

Each pole was attached via a steel bond and fixed pulley to a winch mechanism. The bond was attached at a height of 4m from the ground to the top of each pole.

The pulling bond was passed through a fixed pulley located at the diagonal mid point from each hole. The fixed pulley was anchored using a “duck bill” type ground anchor. The end of the steel cable was attached to a pulley block arrangement. The pulley arrangement was driven by a capstan winch drive. The winch drive and pulley arrangement applied an even “jerk” free constant load to the pole top. The Capstan winch was attached to the Land Rover.

Poles 5 and 6 were however attached directly to the Land Rover.

Logger Details **Squirrel Type 1283**

All tests:	Channel 1	ground temp
	Channel 3	air temp
	Channel 12	25kN load cell
	Channel 11	25kN load cell
For poles 3 & 4	Channel 10	50kN load cell

Load Cell Details **Vekker Plate Load Cell, 25 kN and 50 kN Types**

4.3 Pole Test Results

Poles 1 and 2

Poles 1 and 2 are comparable, both pole bases are buried in the same soil type in excavated holes. Each hole was back filled and tamped down using similar methods. pole 2 has Permasoil added to the back fill. The same winching mechanism and ground anchor was used for both tests.

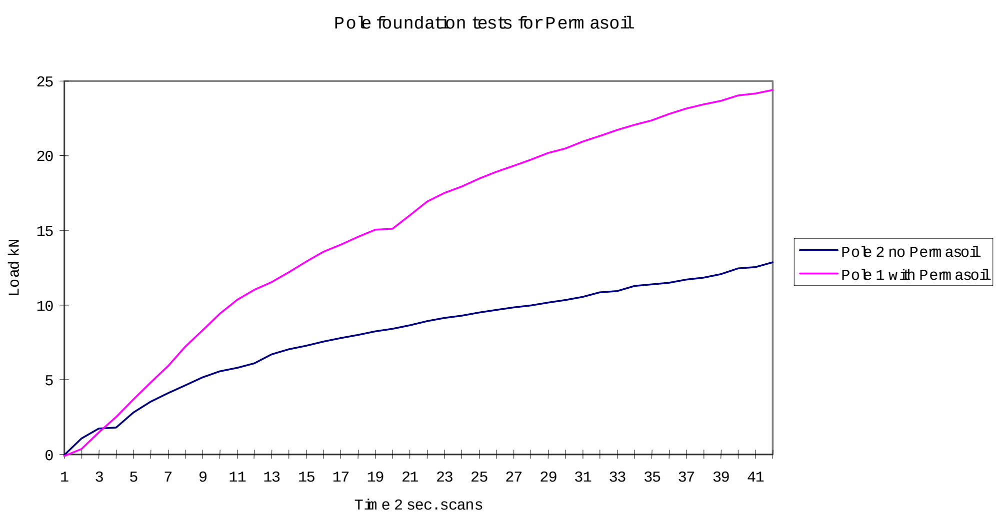

Table 1

Pole 1 test stopped at 24.5 kN. Pole showing signs of breaking. Pole 2 test was stopped at 12.75kN

Pole 1 took greater applied load to move it through an angle of approx 10 deg. the pole was showing signs of breaking. Pole 2 was more easily moved and was pulled over through an angle of approximately 45 deg.

Poles 3 and 7

Pole 3 was buried in an excavated hole with one block attached to the base then back filled and tamped down.

Pole 7 is the same pole in the same position back filled with the addition of Permasoil.

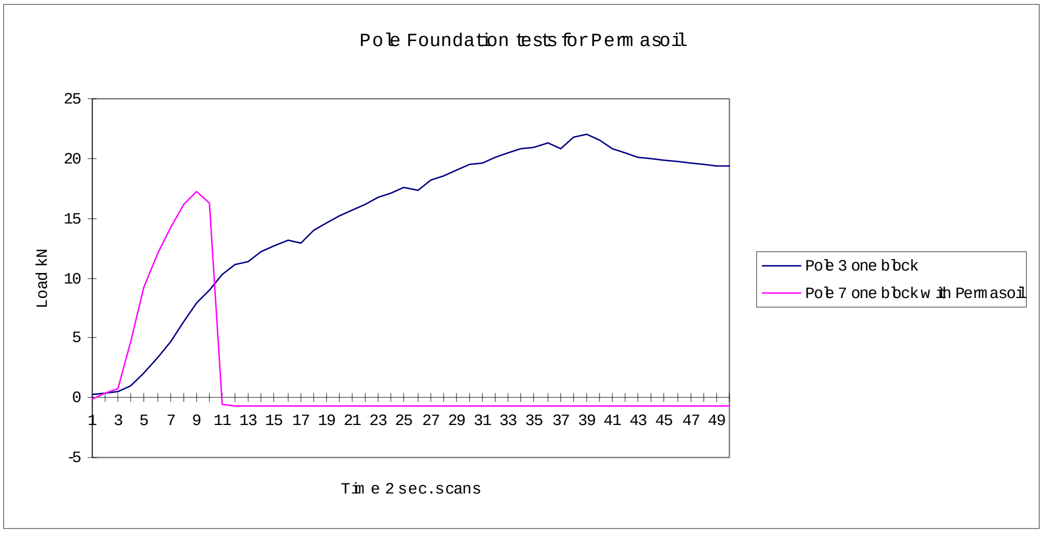

Table 3

Pole 3, movement immediate after test start. Test stopped at 22.75 kN. Angle of pole approximately 60^{o}.

Pole 7 failed and there was only slight movement in ground before pole failed.

Poles 4 and 8

Pole 4 was buried in an excavated hole with two blocks attached to the base then back filled and tamped down.

Pole 8 is the same pole in the same position back filled with the addition of Permasoil.

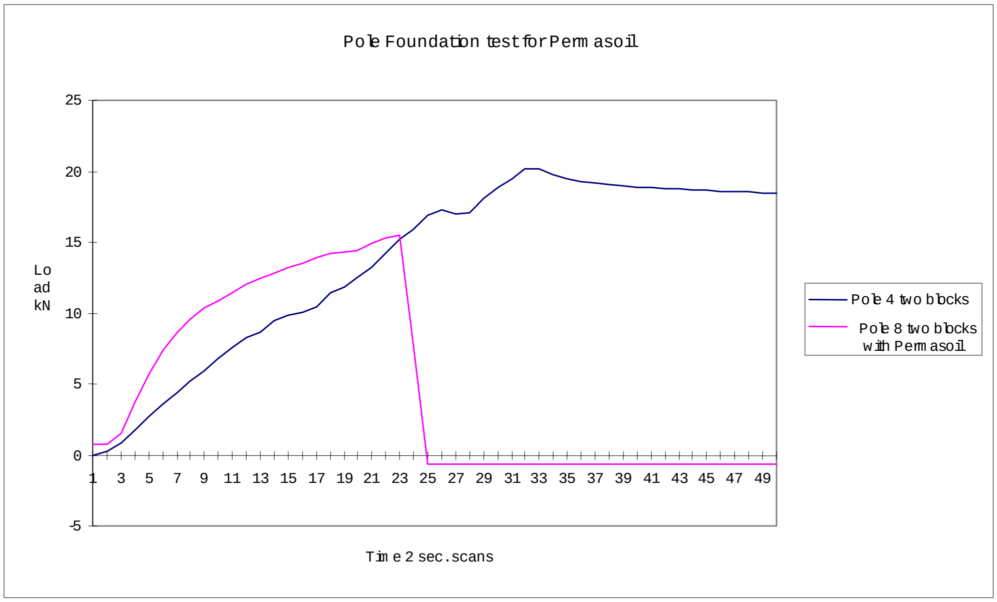

Table 4

Pole 4 test stopped when pulley block reached ground anchor. Pole was bent and showing signs of breaking. Test stopped at 19.18 kN on Pole 4.

Pole 8 failed with little ground movement. Failure at 15 kN.

Poles 5 and 6

Poles 5 and 6 are both in augured holes, with similar ground conditions. pole 6 has Perma-Soil added. The same winching mechanism was used for both tests.

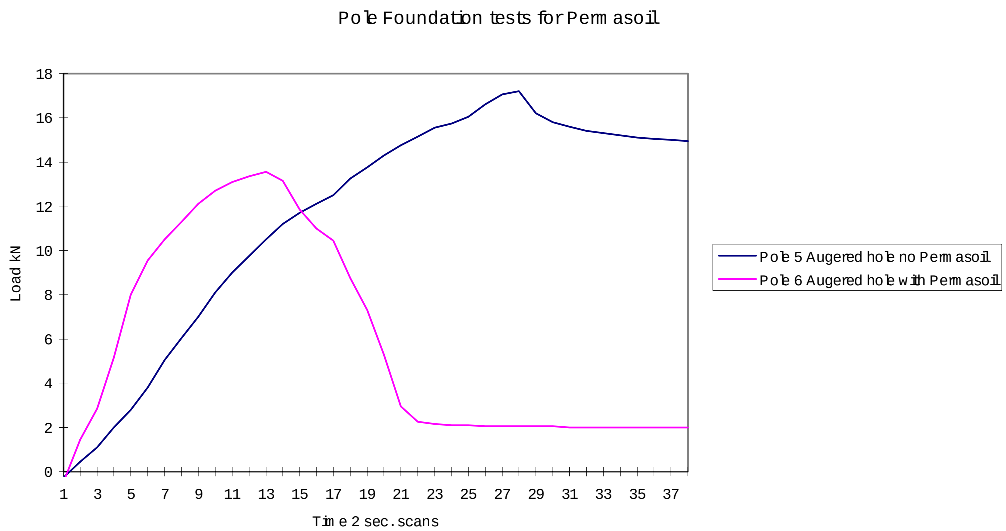

Table 4

Pole 5 pulled over to approximately 45^{o} prior to stress being removed. Test load stopped at 17.5 kN.

Pole 6 pulled over to 20^{o} from the vertical. Load at end of test 13.5 kN.

4.4 Analysis of Test Results

It should be noted that every effort has been made to carry out these tests in the same manner. Due to the nature of the installations, the positioning of the ground anchors relative to the structure being pulled has varied. The results have however been calculated relative to a direct horizontal load on the structures.

Table 5 below details the Horizontal loads applied to the structure as a direct comparison prior to the test being stopped. Each test was stopped due to the following:-

(i) The structure was stressed to breaking load
(ii) The structure had been pulled over to an unacceptable limit
(iii) The load reached was beyond what would be acceptable in real conditions

Pole No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Distance from pole (m)	3.62	3.48	2.9	3.7	12	12	5.5	5.5
Dynamometer Load (kN)	24.5	12.75	22.75	19.8	17.5	13.5	18.8	15
Horizontal Load (kN)	16	8	13	13	16.5	12.8	15	12

Table 5

Pole 1, Standard Pole erected in Perma-Soil treated soil
Pole 2, Standard Pole erected in excavated soil
Pole 3, Standard Pole with one standard block attached, non treated soil
Pole 4, Standard Pole with two standard blocks attached, non-treated soil
Pole 5, Standard Pole erected in Augured Hole
Pole 6, Standard Pole erected in Augured Hole, treated with Perma-Soil
Pole 7, Standard Pole with one standard block attached, treated with Perma-Soil
Pole 8, Standard Pole with two standard blocks attached, treated with Perma-Soil

In considering the information above it can be seen that there is a significant range in the loads that were applied. The pole pairings are 1-2, 3-7, 4-8, 5-6.

Generally an unstayed, therefore intermediate or 'in line' structure would never have a requirement to have such loads applied to it in service, particularly on conductors up to 50mm^2 ACSR or 32mm^2 Copper equivalent. The pole top horizontal loading on an 'in line' structure would generally be in the region of 6.6 kN if we consider a conductor with a Maximum Conductor Pressure (MCP) of 2kg/m on a 150 m basic span.

Poles 1 and 2

A load of 24.5 kN was recorded on the digital dynamometer, at this point the test was stopped. This load equates to a horizontal load at the pole top of 16kN with a moment of force at the fulcrum point in excess of this. Using the information in chapter 3.1 above and assuming the soil to be Good/Average therefore **'k'** is equal to 471000 $N/m^2/m$

Pole planting depth = 1.5 m
Pole diameter = 0.3 m

$$\text{Moment of resistance} = \frac{471000 \times 0.3 \times 1.5^3}{10} \text{ N m}$$

$$\mathbf{= 47688\ N\ m}$$

If we consider Pole 1 the horizontal load applied to the pole was 16000 N, the pole top had moved approximately 10^o at this applied force.

The load is applied at a distance above the fulcrum of 4 m + h/√2 m

Distance	= 4 + 1.5/1.06 m = 5.415 m
Moment of force due to the conductors	= 86641.5 N m
No wind loading will be considered	

Total overturning moment **= 86641.5 N m**

Pole 2 recorded a horizontal load of 8000 N. At this point the pole top had moved approximately 45^o at this applied force.

The load is applied at a distance above the fulcrum of 4 m + h/√2 m

Distance	= 4 + 1.5/1.06 m = 5.415m
Moment of force due to the conductors	= 43320.7 N m
No wind loading will be considered	

Total overturning moment **= 43320.7 N m**

Pole 2 calculation would indicate that the foundation backfill would have been sufficient to withstand the overturning moment yet we know that the pole did not withstand the load applied and moved quite considerably.

If we therefore consider that the maximum rupturing intensity of the backfill **'k'** is less than that considered for Good/Average ground and the value for Average/Poor of 314175 $N/m^2/m$ should therefore be used.

Pole planting depth = 1.5 m

Pole diameter = 0.3 m

$$\text{Moment of resistance} = \frac{314175 \times 0.3 \times 1.5^3}{10} \text{ N m}$$

$$= \mathbf{31810\ N\ m}$$

This would therefore indicate why the pole moved at the lower loads. What is particularly interesting is the improved stability of the structure in the Perma-Soil foundation. The results would indicate that the Perma-Soil treated foundation in Pole 1 has improved the rupturing intensity by more than double that of Pole 2. This clearly shows that the foundation can be improved from an Average/Poor condition to Good. The maximum rupturing intensity for Good soil is **71145 N m**. For a 10^o shift from the vertical at a load of **86641 N m** the soil rupturing intensity would appear to be even better than that given for Good soil conditions.

It can therefore be seen that on this particular test there is a significant improvement in the ground resistivity relative to strength on the Perma-Soil treated area.

Poles 3 and 7

The foundation capability can be significantly improved by introducing a block below ground level this has been illustrated in Chapter 3.1 above. The horizontal loads applied to the structure were again very high and therefore resulted in failure of the foundation in Pole 3 and failure of the structure in Pole 7.

Pole 3 recorded a horizontal load of 13000 N. At this point the pole top had moved approximately 45^o due to the applied force.

The load is applied at a distance above the fulcrum of 4 m + $h/\sqrt{2}$ m

Distance	= 4 + 1.5/1.06 m = 5.415 m
Moment of force due to the conductors	= 70396 N m
No wind loading will be considered	

Total overturning moment **= 70396 N m**

Using a block in reference to Chapter 3.1 it can be seen that the resistance is increased by:-

$$314175 \times 0.25 \times (1.5/\sqrt{2} - 0.5) \text{ N m} = \mathbf{44{,}036\ N\ m}$$

adding this figure to the pole resistance

$$\text{Moment of resistance} = \frac{314175 \times 0.3 \times 1.5^3}{10} \text{ N m} \quad = \mathbf{31810\ N\ m}$$

Total moment of resistance with one block should therefore be

$$31810 + 44036 = \mathbf{75846\ N\ m}$$

It can be seen that the overturning moment is approximately the same as the figure calculated for moment of resistance. As the pole is stressed there is bound to be some movement as the foundation and area around the structure is compacted through the moment of force applied. On Pole 3 however there was still a 30^{o} movement witnessed at pole top.

Pole 7 has been backfilled with the addition of Perma-Soil. A horizontal force of 15000 N was recorded when the pole failed. The pole failure would have been due to the crippling effect of the load applied to the top of the pole. Significantly only slight movement in the structure at pole top was witnessed prior to failure. This is extremely positive and once again indicates the improved moment of resistance of ground by the addition of the Perma-Soil.

Total overturning moment **= 81226.5 N m**

It can be seen that the total ground moment of resistance with one block of **75846 N m** has been exceed by the overturning moment, yet no failure of the foundation was observed.

Once again an improvement in the ground resistance to the forces applied have been seen between these two tests.

Poles 4 and 8

In analysing the results of Poles 1-2 and Poles 3-7 a pattern is emerging relating to the potential improvements in foundation stability the use of Perm-Soil may bring. There is however a limit due to the structures capability to withstand the loads being imposed on it due to the crippling effect.

The calculated total overturning moment for Pole 4 was **73585 N m,** the structure was showing signs of failure at this point as the ground resistance exceeded that of the pole strength. It can once again be seen however that Pole 8 installed with Perma-Soil has much more stability. Unlike Tables 1 and 2 the loads detailed in Table 3 (see Section 4.3) are relatively similar and follow a much more similar pattern. In both Poles 4 and 8 the foundation capability is generally greater than the strength of the structures.

Poles 5 and 6

The two augured installations provided some curious results at first glance. If we consider the previous examples there is a definite improvement on ground resistance where the Perma-Soil soil stabiliser has been used. It should be noted that augured installations are notably deeper than the standard installation (approx. 2.40 m). The augured installation in this case was at the standard depth of 1.5 m. The increased depth would generally compensate for the use of a block or poor backfill. Table 4 however does show that the structures follow the same pattern that has been already established, with Pole 6 offering greater resistance to movement in the early stages of the test. This can be explained through the additional surface area that the Perma-Soil treated backfill has provided.

If we consider Pole 5 the general area of the pole at 0.3 m in an undisturbed ground, due to the auger being used the surrounding soil can be considered as Good ground

(628214.7 $N/m^2/m$) then;

Pole planting depth = 1.5 m

Pole diameter = 0.3 m

$$\text{Moment of resistance} = \frac{628214.7 \times 0.3 \times 1.5^3}{10} \text{ N m}$$

$$= \mathbf{71145 \text{ N m}}$$

The applied load is calculated as **94764 N m** which is beyond the theoretical moment of resistance and would certainly account for failure occurring. The pole moved quite considerably to an angle of 45^o.

The area around Pole 6 has been backfilled with the Perma-Soil mix. A load of 69313 N m is calculated as the total overturning moment applied to this structure during the test. The pole moved to a position of 20^o to the vertical and then began to show sign of pole failure. This is actually a positive result in relation to the foundation stability.

It should be pointed out that although the load applied to Pole 5, prior to the test ending, exceeded that of Pole 6 this load was not acting in a direct crippling effect. The forces applied to the top of the Pole 5 were in effect pulling the pole due to its foundations failure to withstand the horizontal forces.

5 Conclusions

It can be seen that on all tests carried out there is a significant increase in the soil/foundation resistivitiy to the mechanical loads imposed on the structures where the Perma-Soil stabiliser has been introduced. It should be noted that the loads applied to the top of these structures are unlikely to be applied under even the most severe conditions in the field.

As mentioned in the earlier text a good foundation is fundamental to providing a sound overhead line design. On the limited tests that EA Technology have carried out the Perma-Soil system would appear to assist in providing improved stability for supports.

It can be considered that where average to poor foundations are identified the Perma-Soil stabiliser may provide sufficient improvements in the foundation capability to improve the soil quality to that of a ‘Good’ backfill. For overhead line calculations this would in effect provide additional windspans for construction without the need to install blocks in some circumstances.

The cost of the Perma-Soil product per installation is quoted to be in the region of ~~£14.00~~ ***(New Summer 2000 Price, £6.00)***. The cost of a standard 1300 mm x 250 mm x 125 mm block is in the region of £10.00 - £12.00. The difference in the price is obviously marginal, however, the costs associated with installation would generally be greater with the installation of a blocked pole. This is due to the volume of spoil that has to be excavated in order to install the structure. The cost of pole installation can be estimated at anything between £400.00 and £800.00 per installation depending on the circumstances, grade of pole and of course foundation capability.

The Perma-Soil system if applied in a pragmatic manner could therefore provide benefits in both savings and design. The savings may be in the area of less requirements for blocks but more importantly benefits will be seen in improved stability where there tends to be poor soil or backfill for foundation support.

Information has been provided in Appendix 1 detailing typical span lengths for foundation types considered in the UK environment. It can be seen that the tables indicate the differences between the Average/Poor foundations and those for Good. It can therefore be considered that with the application of the Perma-Soil product, in relation to the tests carried out by EA Technology at Chorley, the windspan values could be improved by introducing the Perma-Soil product during installation. The tables illustrate this by showing as an example a 9 m Stout pole in Average/Poor conditions with a Maximum Conductor Pressure (MCP) of 2, the windspan for ‘No Blocks’ is 61 m. The same 9 m Stout pole in Good soil conditions can have a windspan of 130 m. It should be noted that as a precaution against misinterpretation of soil conditions and possibly poor mixing techniques that it would be more prudent to consider the improvements to Good/Average conditions with a windspan increase to 96 m. Still this would provide significant improvement and may remove the need to install a Block in the Average/Poor soil conditions. There is no doubt that these considerations may provide considerable benefits to users.

Appendix 1

Soil Classification GOOD

Description of soil type from BS5649

GOOD - Compact well graded sand and gravel, hard clay, well graded fine and course sand, decomposed granite rock and soil.

Good material should be drained and in locations where water will not stand.

Soil Classification GOOD/AVERAGE

GOOD/AVERAGE- Compact fine sand, medium clay, compact, well-drained sandy loam, loose coarse sand and gravel.

Average soil should drain sufficiently well that water does not stand on the surface.

Soil Classification AVERAGE/POOR

AVERAGE/POOR- Soft clay, clay loam, poorly compacted sand clays containing a large amount o slit and vegetable matter, and made ground.

Poor soils will normally be wet and have poor drainage

Appendix 2

1 Electrical Resistivity Tests Poles 1 to 4

Sheet 1

2 Resistivity Tests Poles 5 to 8

Sheet 2

Appendix 3

Figure 1 shows the final position of poles 1 and 2. Pole 1 with Perma-Soil additive is in the fore ground.

Figure 2 there was less ground disturbance evident around the base of pole 1.

Figure 3 shows the 'true' angle of pole 2.

Figure 4 the ground disturbance around the base of pole 2.

Figure 5 shows pole 4 with two blocks bending under load.

Figure 6 this is the typical soil condition after the addition of Perma-Soil.

Figure 7 and 8 the base of pole 8 the pole has snapped with little evidence of ground disturbance.