Southern Testing
Environmental & Geotechnical

Headstone Stability Load Tests

Desk Studies | Risk Assessments | Site Investigations | Geotechnical | Contamination Investigations | Remediation Design and Validation

Site Address: Union Point, Uckfield, East Sussex

Client: Stone-Safe

Report Date: 26 August 2008

Project Reference: J9676

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Certificate No. FS 29280

Our Ref: DV/EL/J9676
Your Ref:

26 August 2008

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Stone-Safe
The Memorial Stone Centre Ltd
Shripney Road
Bognor Regis
West Sussex - PO22 9PJ

For the attention of Mr. A. Matthews

Dear Sirs,

Re: Headstone Stability Load Tests

We write further to our recent series of load tests carried out at the premises of C. J. Thorne and Co. Ltd, Uckfield, East Sussex on 30th and 31st July 2008.

1 Introduction

The purpose of the tests was to measure and compare the load-deflection relationships between two types of foundation systems used to support memorial headstones. The tests were carried in three soil types. This report describes the two foundation systems investigated, the test arrangement and methods employed to carry out the tests. The resulting measurements are discussed and finally conclusions and recommendations are made.

2 Foundation Systems

Descriptions of the two types of foundation systems investigated are as follows:

2.1 "Pylon System"

The "pylon" system is a propriety system developed by *Stone-Safe*. This system involves two 150mm diameter short concrete "piles" typically about 18" deep (460mm) installed using hand auger techniques. A single threaded bar is installed in the "uncured" concrete over the full length the "piles". A cranked concrete slab is then bolted down directly onto the head of the piles. The memorial headstone is then subsequently bolted down onto the cranked concrete slab. This system primarily develops it lateral stability by the "bending resistance" of the two 150mm diameter piles within the surrounding ground conditions and a small proportion of the bearing resistance of the soil beneath the cranked concrete slab.

2.2 "Pin" System

The "Pin" system is a propriety system that we understand is commonly used to provide stability to a headstone base. We understand that a foundation slab is initially placed down on a prepared soil formation.

A 25mm diameter stainless steel pin is then driven through a hole in the slab into the soil to a depth of approximately 18" (460mm). The memorial headstone is then subsequently fixed onto the foundation slab. This system primarily develops it lateral stability by the "bending resistance" of the 25mm diameter stainless steel pin within the surrounding ground conditions and a proportion of the bearing resistance of the soil beneath the foundation slab.

3 Test Arrangement and Procedure

3.1 Soil Conditions

A series of test areas were initially prepared by C.J. Thorne & Co. Ltd., Civil Engineering Contractors. The soils within each test area were prepared by either stripping the upper materials down to a natural clay formation, which in this case was a brown silty sandy Clay or by excavating out a series of "test pockets" and replacing with a weaker remoulded brown silty sandy Clay or a (fine to coarse) dry Sand material.

Undrained shear strength measurements were carried out in the natural and remoulded clay materials using either a Hand Penetrometer or Shear Vane. Perth Penetrometer Tests were carried out in the sand materials to establish the relative density of these materials.

A general description of these tests are given below:

Hand Vane Test

The hand shear vane test provides a means of determining the undrained shear strength of the tested soil. The apparatus consists of a cruciform vane on an extensible shaft. The vane is inserted into the clay soil and torque applied to the shaft until the soil fails, as indicated by a constant of dropping torque, by shearing on a circumscribing cylindrical surface. The torque at failure is measured and recorded.

Hand Penetrometer Test

The hand penetrometer consists of a spring loaded and calibrated plunger which is forced into the soil. A reading of unconfined compression strength (equal to twice the undrained shear strength) is given on a calibrated scale. In common with other hand methods of strength assessment (e.g. the shear vane) it does not give an accurate indication of bearing capacity in stiff or fissured soils, because of the small test area. The figures are used for strength classification according to the table below.

Hand Penetrometer Value (kPa)	Undrained Shear Strength c_u (kPa)	Description	
		BS5930	BS EN ISO 14688
Less than 20	Less than 10	Very Soft	Extremely Low Strength
20 to 40	10 to 20	Very Soft	Very Low Strength
40 to 80	20 to 40	Soft	Low Strength
80 to 150	40 to 75	Firm	Medium Strength
150 to 300	75 to 150	Stiff	High Strength
300 to 600	150 to 300	Very Stiff	Very High Strength
More than 600	More than 300	Hard	Extremely High Strength

Perth Penetrometer Test

The Perth Penetrometer is a device used for measuring the relative density of sands. It consists of a 16 mm diameter hardened steel probe, which is driven into the soil by successive blows of a 9 kg weight, which freely falls over a distance of 600 mm. The number of blows required for each 50 mm of penetration is recorded, and the test is continued for a depth of 450 mm, according to soil type. Useful information can be obtained by carrying the test past the standard depth, and 2,000 mm and 3,000 mm extensions are used to probe the depth of loose fill or other soil, or to make an estimate of the strength of soils or rock in an auger hole or in the base of an unsupported test pit.

The energy input per square metre is roughly the same as the energy input from the Standard Penetration Test (SPT), and the blow counts recorded in sand are roughly the same as SPT blow counts (but this relationship does not hold for coarse soils). The SPT test is a similar type of test except that much heavier driving weights (63.5 kg) are used. The relative density relationship given for the SPT test is:

Number of Blows (N)	Density
0 - 4	Very Loose
4 - 10	Loose
10 - 30	Medium Dense
30 - 50	Dense
Over 50	Very Dense

The results of the above tests for the three soil types considered are given below:

Soil Type	Hand Penetrometer Value (kPa)	Shear Vane (kPa)	Perth (N) Value
Natural Clay	500	The strength of the natural clay materials exceeded the capacity of the hand vane equipment	N/A
Remoulded Clay	-	38 (average value)	N/A
Dry Sand	N/A	N/A	3

On the basis of the above strength/density measurements the natural clays fall into the very stiff (very high strength) range, the remoulded clays fall into the soft/firm (low-medium strength) range while the sands were in a very loose state.

3.2 Load Test Equipment

A steel load frame was designed and manufactured by Southern Testing, *Stone-Safe* and C.J. Thorne & Co. Ltd. Civil Engineering Contractors. The frame was designed to model a foundation slab and to allow a horizontal pull to be applied. The test arrangements are shown in Figures A and B. The lateral load was applied to a vertical steel box channel welded onto a steel channel forming the base of the load frame. The horizontal load was applied to the vertical steel box section at a height of 2' 6" above ground level using calibrated weights placed on a hanger system. The resulting deflection at the point of " horizontal pull" was measured using a dial gauge (0.01mm/division) connected to a horizontal datum bar.

3.3 Foundations and Test Procedure

To allow the concrete of each pile to cure, approximately one week prior to the tests being carried out a representative from *Stone-Safe* installed their "pylon" foundation system into the three soil types to be tested. To model the cranked foundation base, the soil was removed from beneath the base of the load frame between the two piles. The load frame was then bolted down onto the head of the two "piles" using the threaded rods protruding from the top of each "pile" (refer Figure A).

In the case of the "pin" system, Southern Testing placed down a thin bed of sand to remove any unevenness between the steel channel base (typically less than 10mm thick) and the test soil formation. The load frame was then firmly bedded down onto the formation by "rotating" the frame on the sand bed. The pin was then driven through a hole in the frame into the underlying soil (refer Figure B).

Following the above procedures the horizontal load was then applied to the frame. Typically the load increment applied was 20kg and using the dial gauge the resulting deflection for each increment was monitored over a period of time until the rate of deflection essentially stabilized or reduced to approximately 0.1 mm/min. The test was terminated when either a total load of 150kg was applied to the system or if the load increment and resulting rate of movement indicated **failure** of the foundation system.

Following the above tests, a load test was carried out on the steel load frame itself by rigidly bolting the frame down onto a concrete floor slab. The load deflection relationship of the frame was then determined. Using the results of these tests corrections were then applied to the field load test data to remove the inherent flexural characteristics of the frame.

4 Test Results

The results of the six load tests and the load–deflection plot for the frame are given in Figures 1A-6A and Figure I. In addition Figures 1-3 are also given that provides a direct comparison of load deflection characteristics for the two foundation systems considered and three soil types investigated.

Referring to Figures 1-3, a summary of the load-deflection behaviour is given below:

Soil Type	Foundation System	Deflection (mm) @ 50kg and 150kg horizontal loads		Yield/Failure of the System and Remarks
		50 kg Load	150kg Load	
Natural Clay (C_u=250kPa)	"Pylon" System	0.3	22	No yield/failure observed. Slight residual deformation of 4mm on unloading was recorded
	"Pin" System	25	Failure of system @70-90kg load increment	Probable onset of yield of the system occurred at the 30-50kg load increment. Failure of the system occurred at the 70-90kg load increment.
Remoulded Clay (C_u=38kPa)	"Pylon" System	0.3*	16	No failure observed. Possible onset of yield @110-150kg loads increment. Residual deformation of 11mm on unloading was recorded
	"Pin" System	57 (Yield of system @30-50kg load increment)	N/A	Yield/failure of system occurred @30-50kg load increment. Test continued until 90kg when complete failure occurred.
Very Loose (dry) Sand (Perth "N"=3)	"Pylon" System	11	Failure of system @130-150kg load increment	
	"Pin" System	N/A-Failure of System occurred @30-50kg load increment	N/A	

* Deflection estimated: system appeared "stable" and therefore an increased load increment of 30-70kg applied.

5 Conclusion

The above results demonstrate that relative to the "Pin" foundation system, the *Stone-Safe* system is a more stable form of foundation system for the ground conditions tested. The main factors that influence a system that relies primarily on its stability by the "bending resistance" of the supporting foundations is the depth and diameter of the piles/pin, the undrained shear strength in the case of a cohesive material (clay) and in the case of a drained granular material (sand/gravel) its state of relative density and the presence of a water table. Both foundation systems tested were installed to the same depth e.g. 18" (460mm) and similar soil conditions however in the case of the *Stone-Safe* system, two piles of 150mm diameter are employed while the "Pin" system tested has a single "Pin" of only 25mm diameter.

As a first approximation, we have carried out an analysis of the *Stone-Safe* system by treating them as "short piles".

The results of this analysis indicate that for a cohesive soil i.e. a clay material, a minimum theoretical Undrained Shear Strength (C_u) of about 35kPa would be required for the two 150mm diameter, 18" (460mm) deep pile system to sustain the ultimate horizontal load of 150kg acting at 2' 6"(760mm) above ground level. Where the cohesive soils are weaker than 35kPa then caution is required and allowances should be made for deepening of the piles and possibly accepting greater amounts of deflection.

In the case of a cohesionless soil model in a dry condition i.e. water table below the toe/base of the "pile" then we estimate the following pile depths for various states of relative density:

Height of 150kg load=2.5ft	Cohesionless soil (no groundwater) - Assuming 2No 150mm diameter piles		
"N" Perth Value	"Pile" Depth** (ft)	"Pile" Depth** (m)	"Pile" diameter (m)
3*–10	2.2	670	150
11-25	2	610	150
26-38	1.9	580	150
39+	1.8	550	150

*Recommend minimum acceptable "N" value.

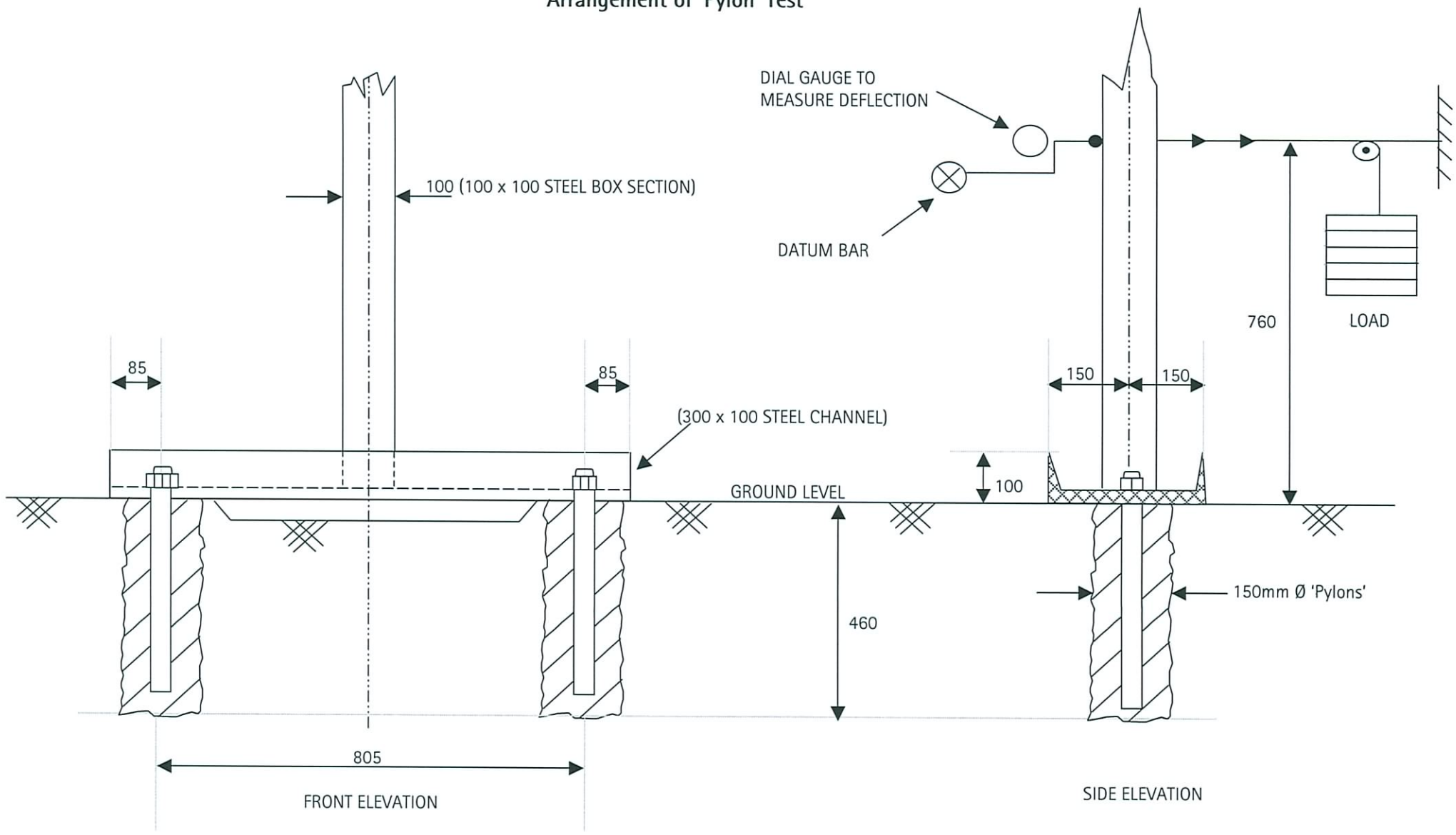
**The above analysis for cohesive and non cohesive soils assumes that the soils are natural materials and not made ground or an unsuitable founding material i.e. backfill materials, imported soil material, topsoil, peat etc. and that the full length of the "pile" shaft penetrates into the natural bearing stratum.

It should be noted that in the case of a very loose sand condition, a minimum pile depth of 2.2' (670mm) is indicated. This is consistent with the findings of the full scale tests where the "Pylon" system effectively failed at a load increment of 130-150kg. Accordingly in cohesionless soils it would be prudent to adopt a minimum pile depth of at least 670mm for very loose cohesionless soils reducing to 550mm for very dense soil conditions.

Yours faithfully

D Vooght
For and on behalf of
Southern Testing Laboratories Limited
DDI: 01342 333130
Email: dvooght@southerntesting.co.uk

Arrangement of 'Pylon' Test



Site: Union Point, Uckfield	STL: J9676	Fig No: A
Date: 15 August 2008	Arrangement of 'Pylon' test *(Not to scale)*	

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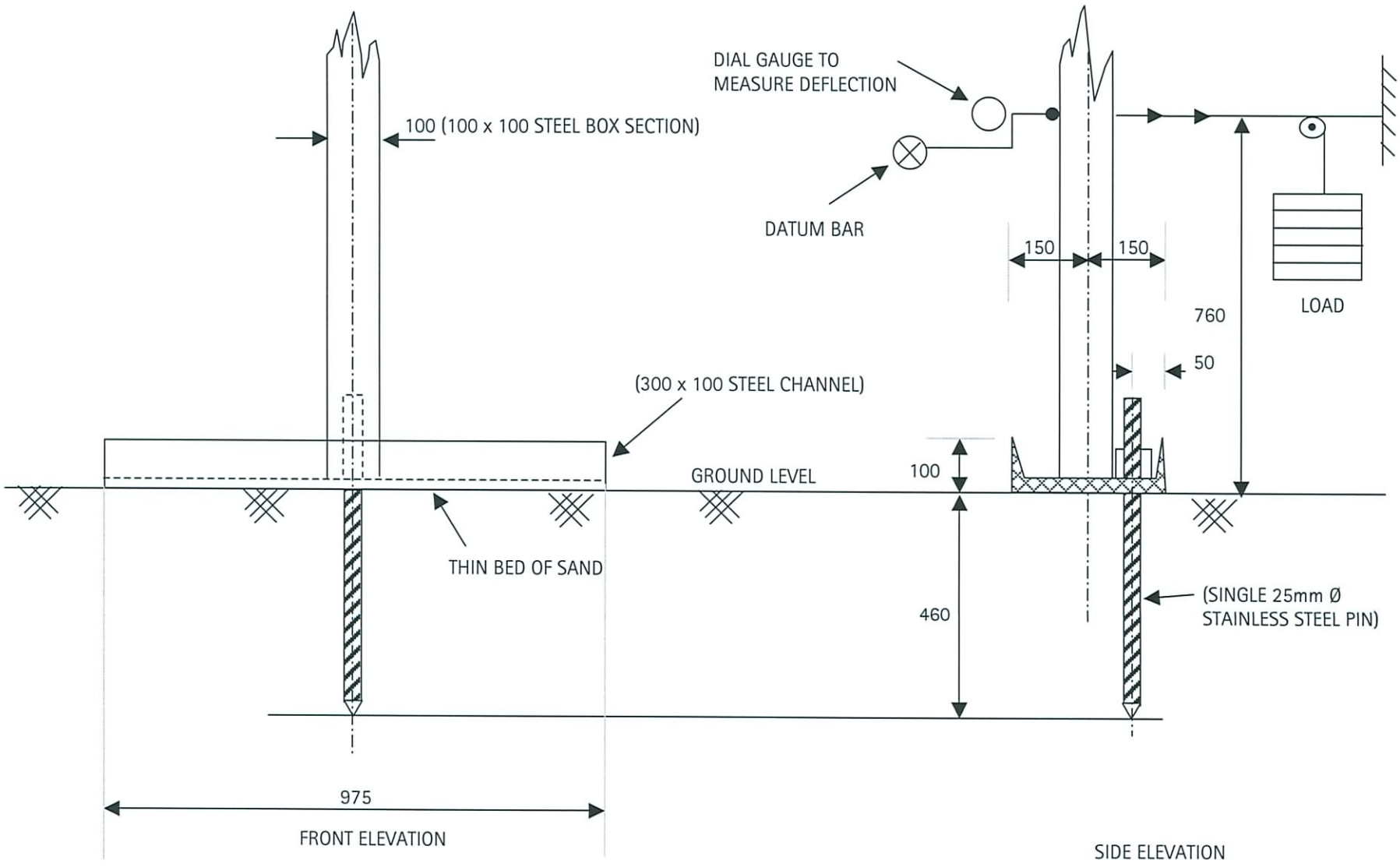
Arrangement of 'Pin' Test



Site: Union Point, Uckfield	STL: J9676	Fig No: B
Date: 15 August 2008	Arrangement of 'Pin' test *(Not to scale)*	

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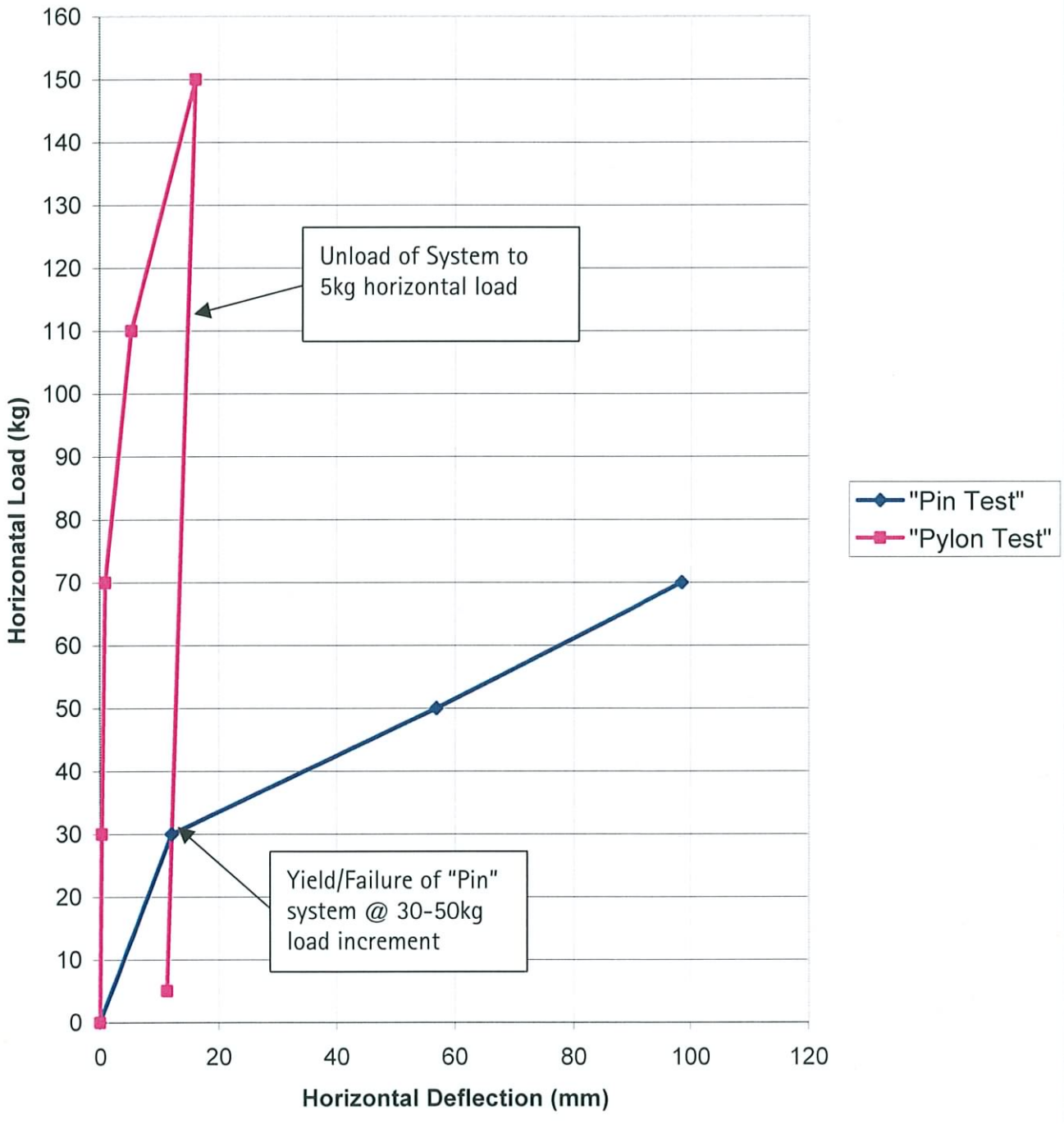
Lateral Load Test for Remoulded Clay Condition



Site: Union Point, Uckfield	STL: J9676	Fig No: 2
Date: 13 August 2008		

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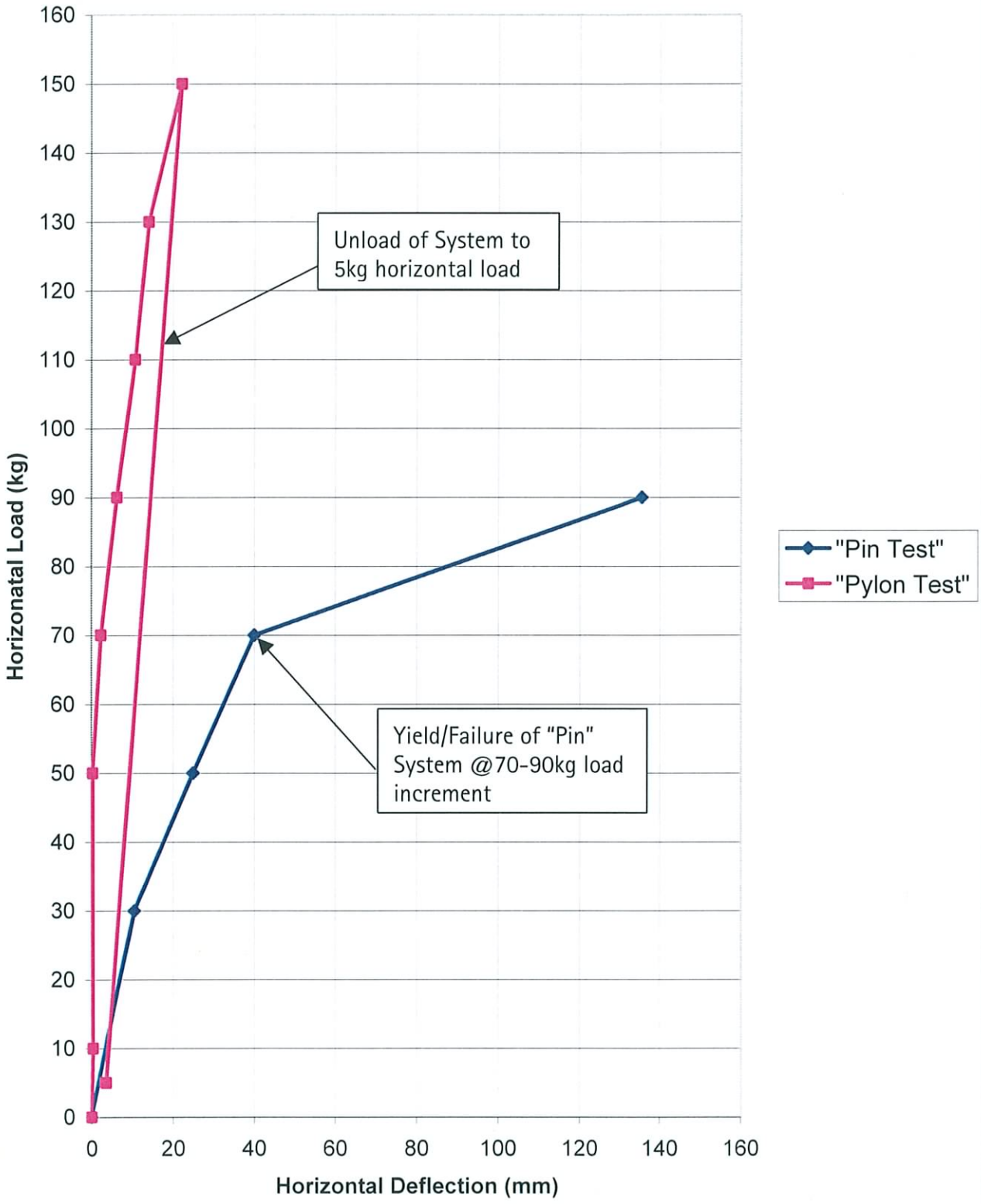
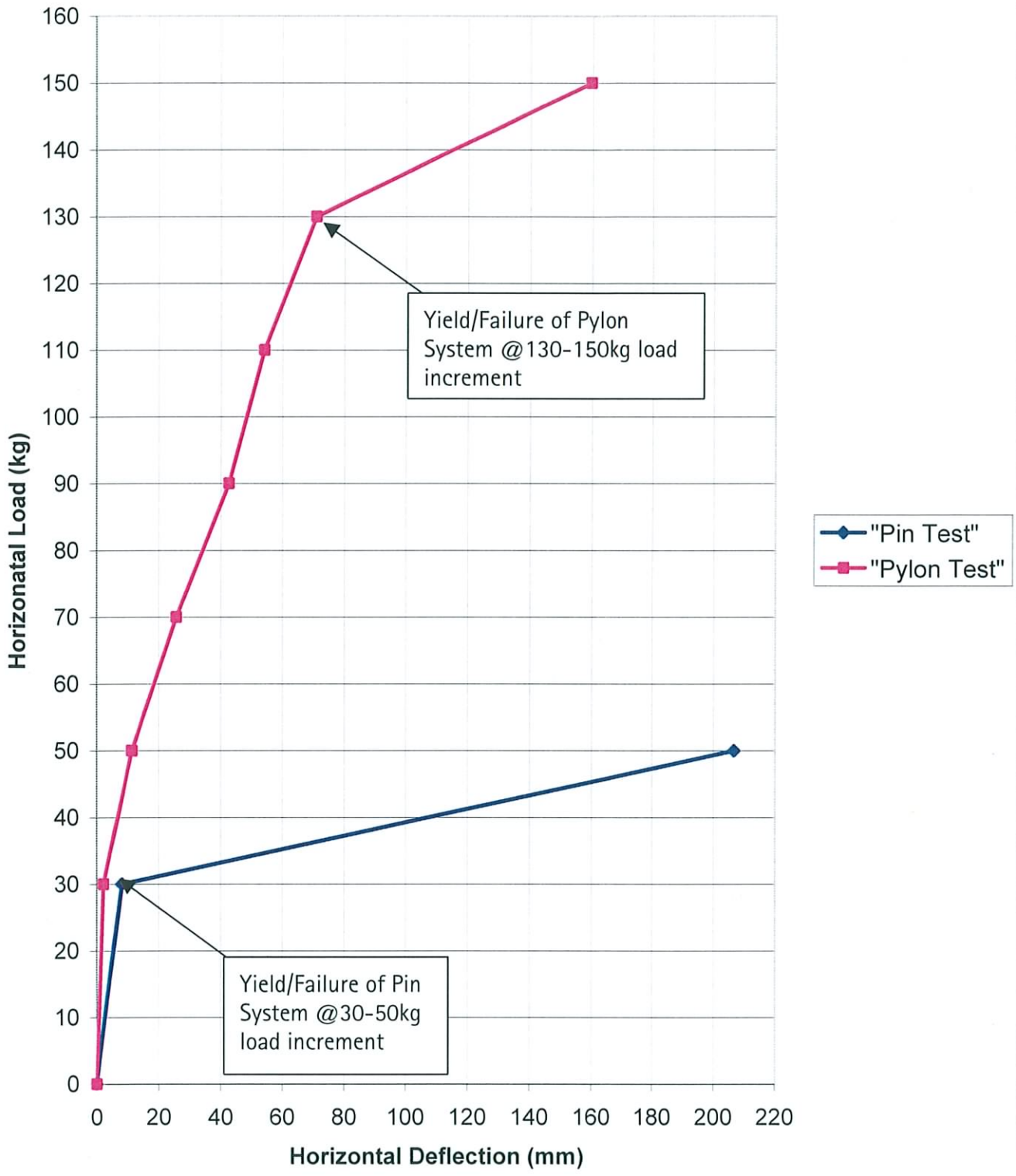
Lateral Load Test for Natural Clay Condition



Site: Union Point Uckfield	STL: J9676	Fig No: 1
Date: 13 August 2008		

Lateral Load Test for Loose Sand Condition



Site: Union Poiint, Uckfield	STL: J9676	Fig No: 3
Date: 13 August 2008		

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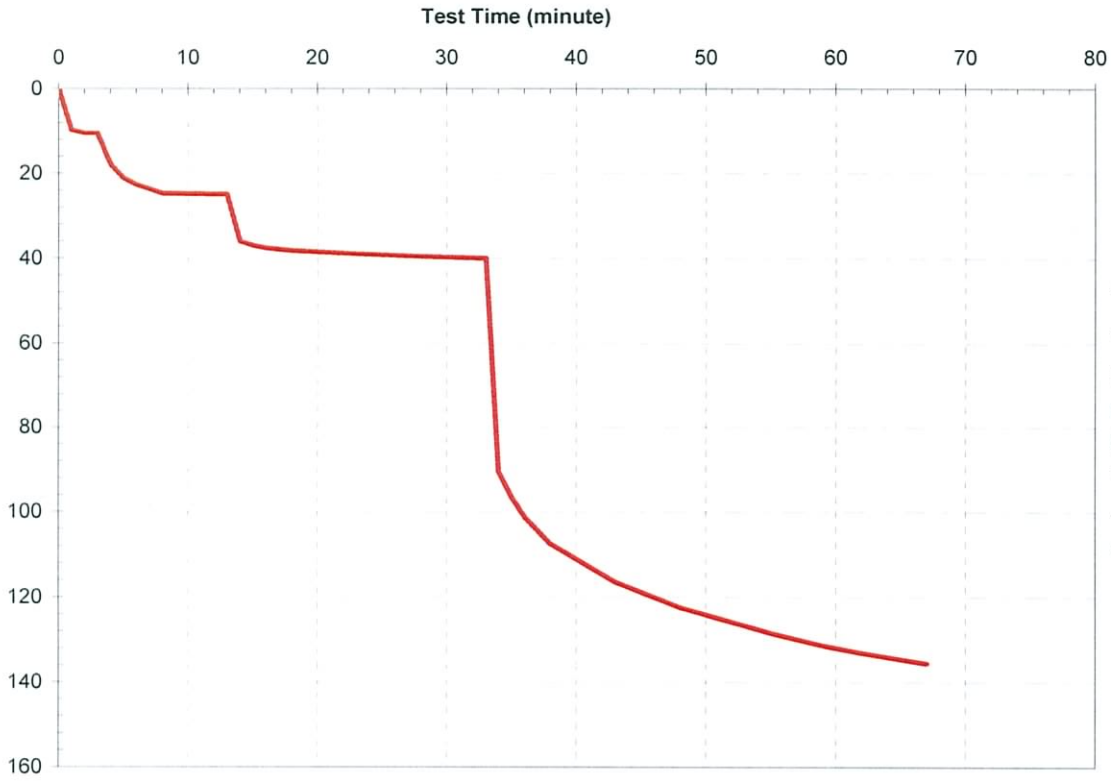
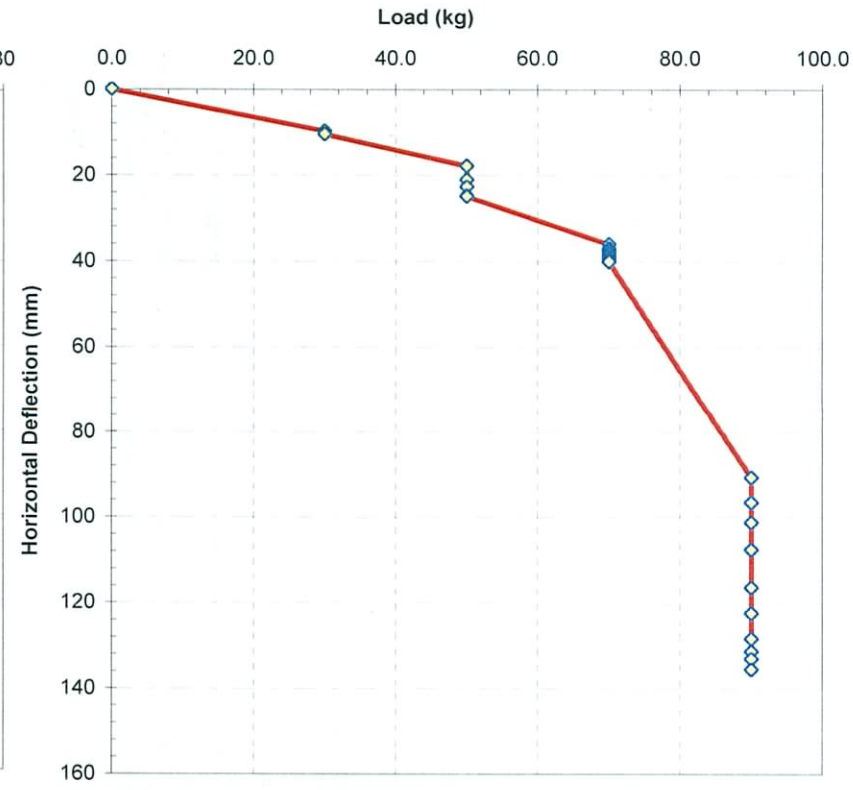
Horizontal Load Test Results

Soil Type & Condition:	Natural Clay	Test No:	1
Weather & Temperature:	Sunny 30 C		
Test Type:	Driven pin at front of load frame		
Notes:		Test Date:	31-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



Site:	Union Point, Uckfield TN22 5SS	**Job No:**	J9676	**Checked By:**	
Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**1A**

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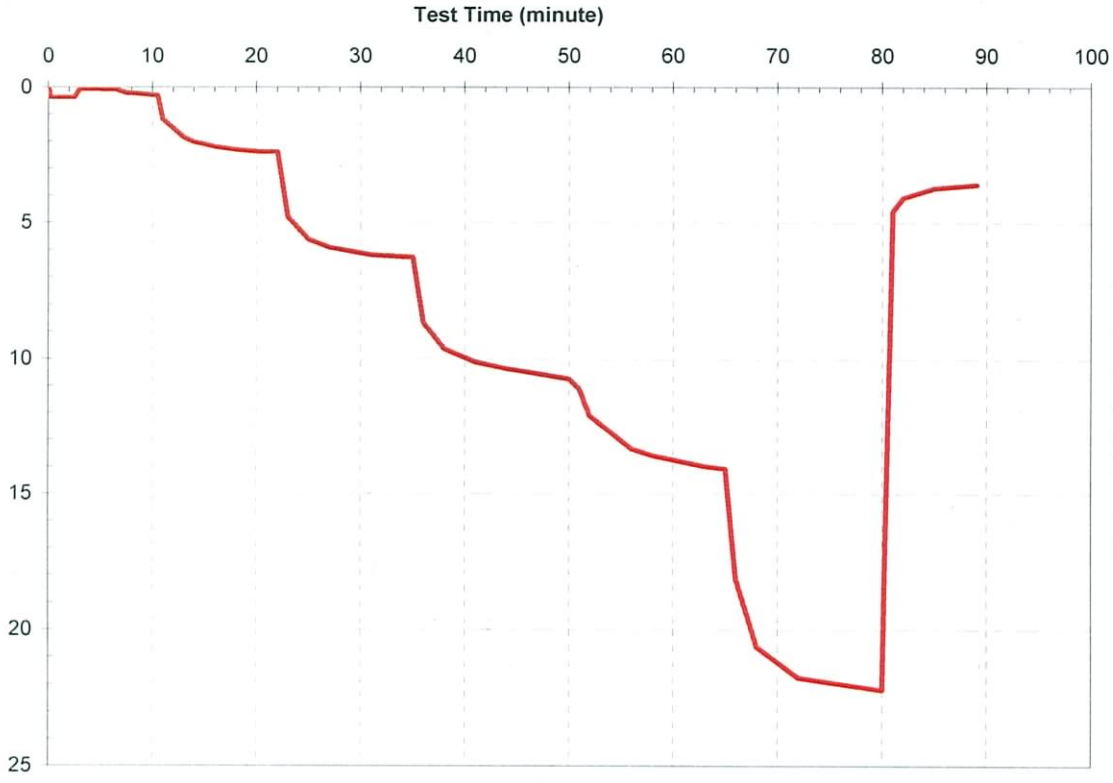
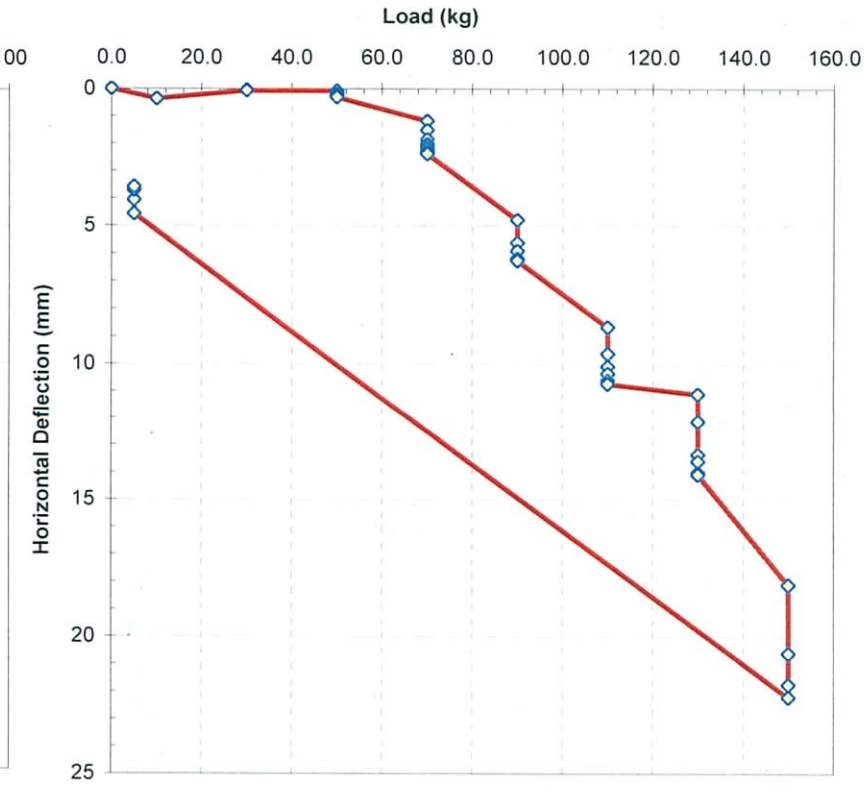
Horizontal Load Test Results

Soil Type & Condition:	Natural Clay	Test No:	2
Weather & Temperature:	Sunny 30 C		
Test Type:	18" "Pylons"		
Notes:		Test Date:	30-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



Site:	Union Point, Uckfield TN22 5SS	**Job No:**	J9676	**Checked By:**	
Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**2A**

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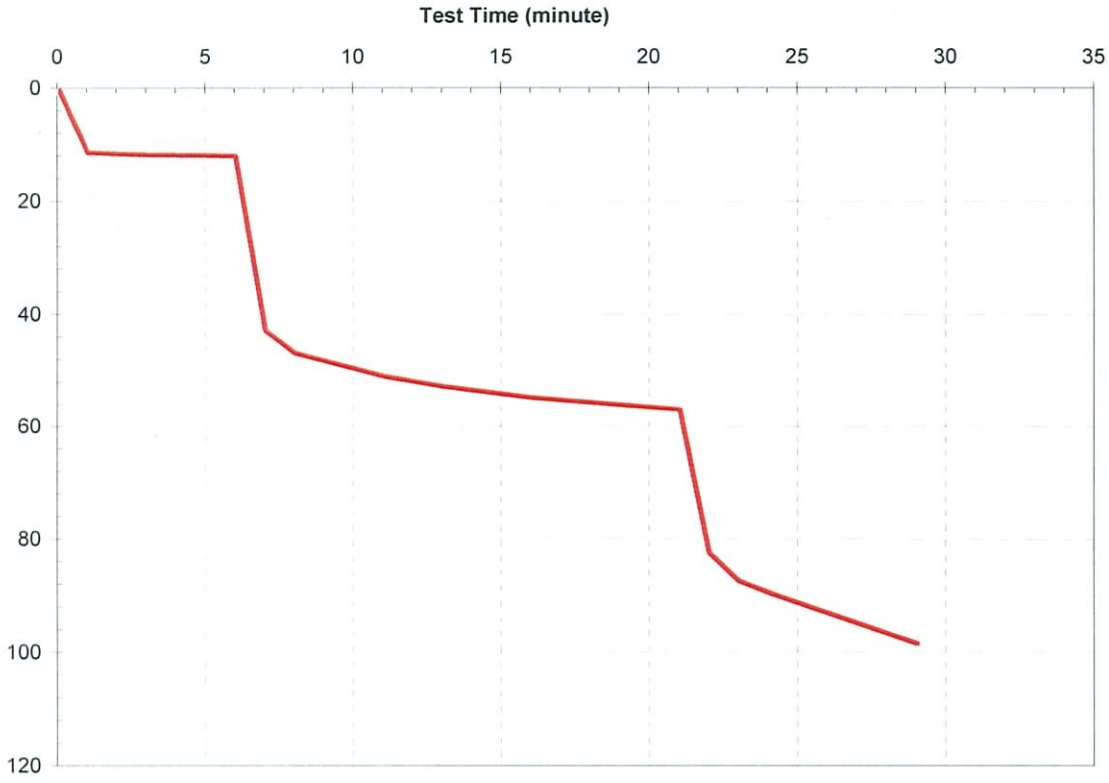
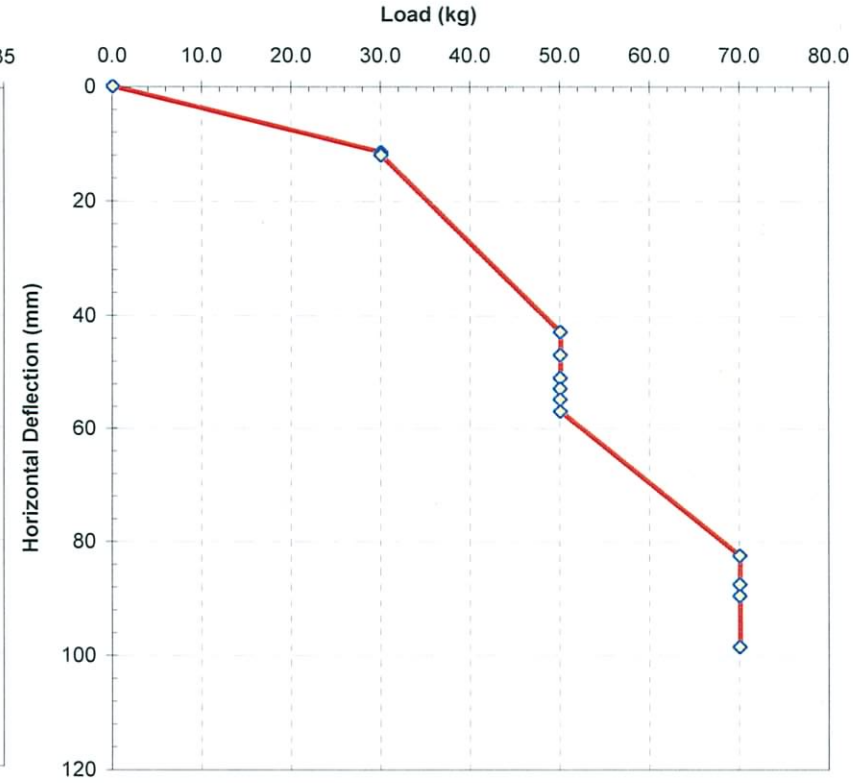
Horizontal Load Test Results

Soil Type & Condition:	Remoulded sandy clay	Test No:	3
Weather & Temperature:	Sunny 30 C		
Test Type:	Driven pin at front of load frame		
Notes:		Test Date:	31-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



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Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**3A**

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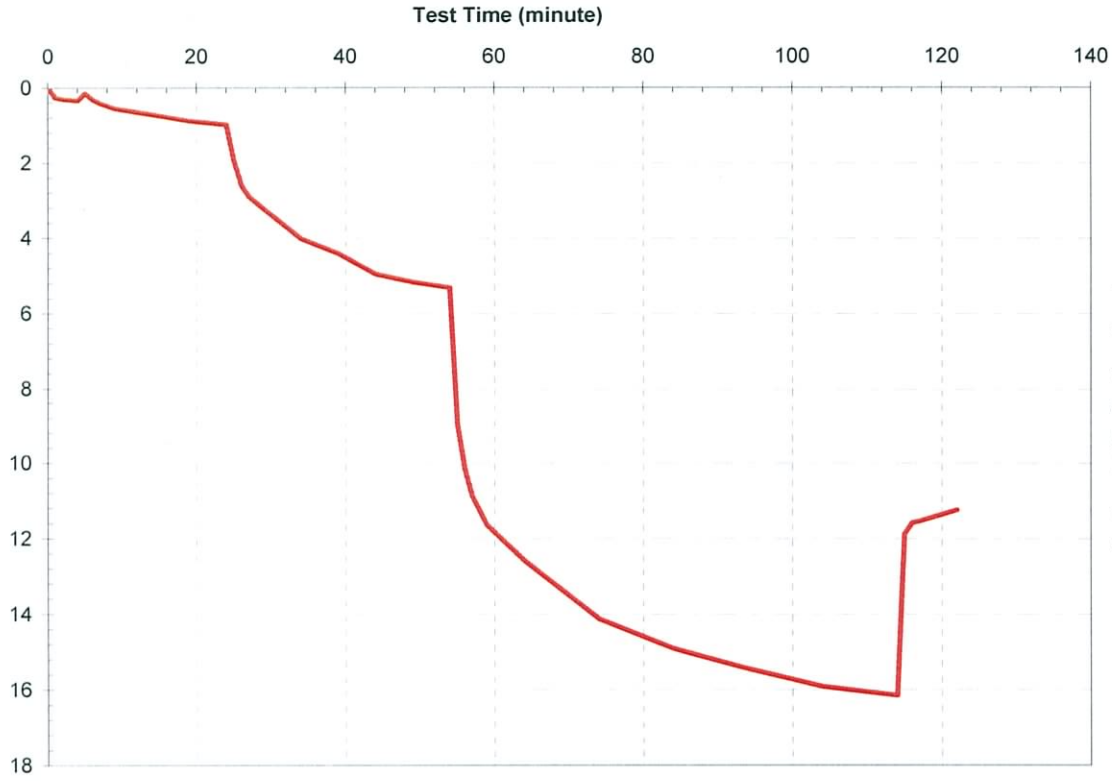
Horizontal Load Test Results

Soil Type & Condition: Remoulded sandy clay
Weather & Temperature: Sunny 30 C
Test Type: 18" Pylons
Notes:

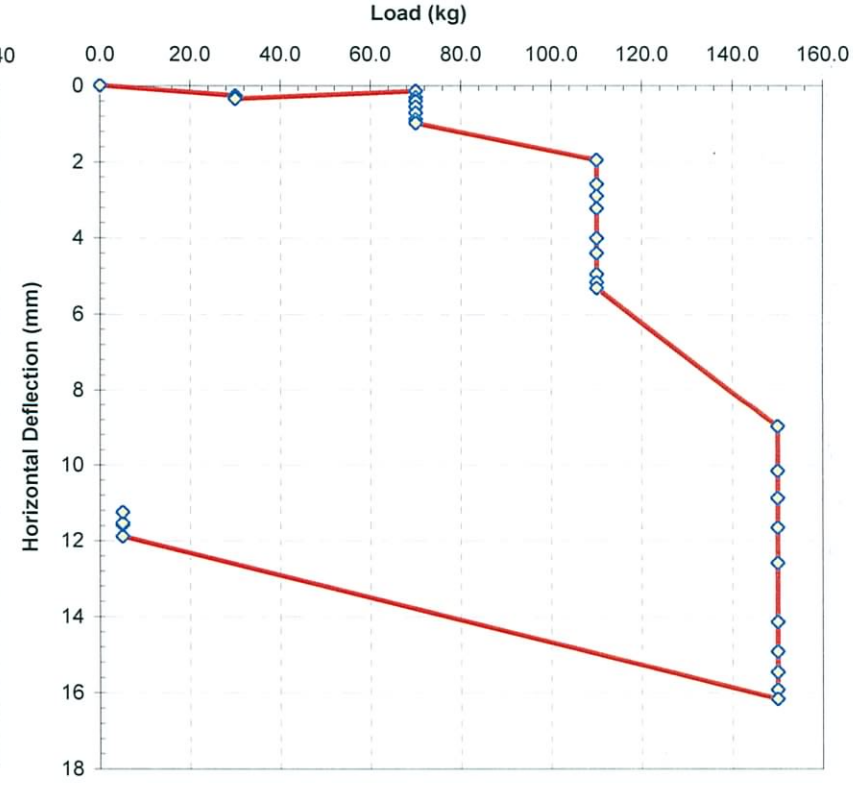
Test No: 4

Test Date: 31-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



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Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**4A**

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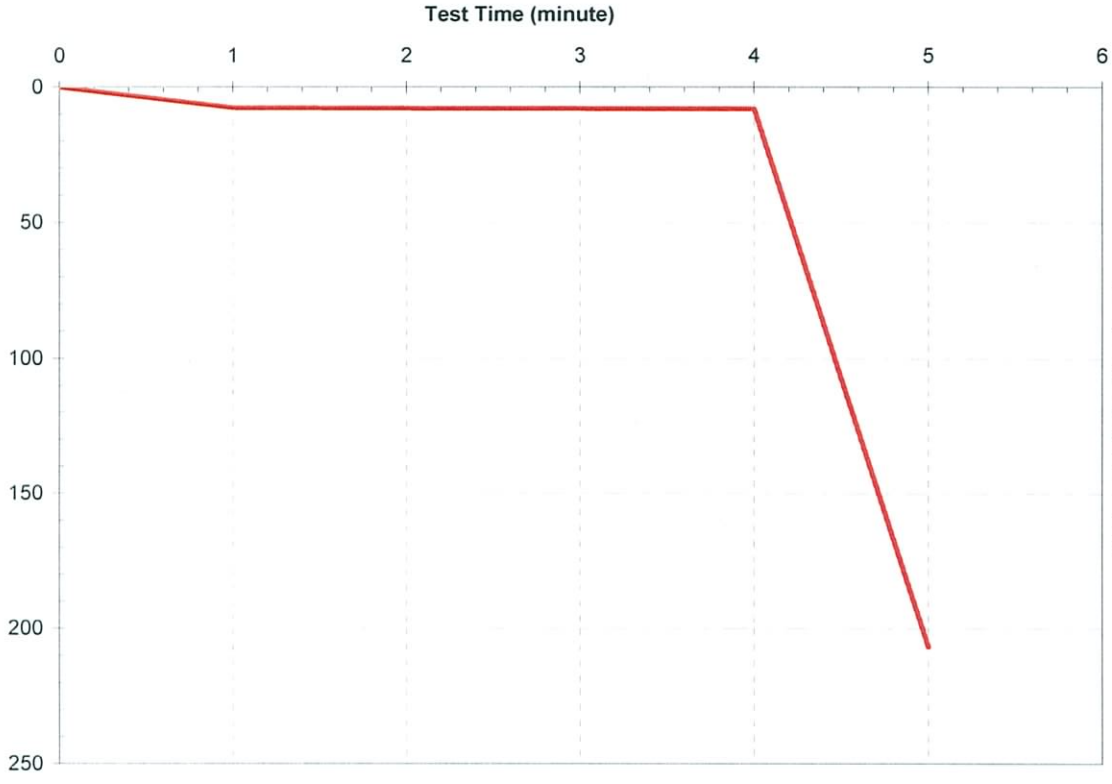
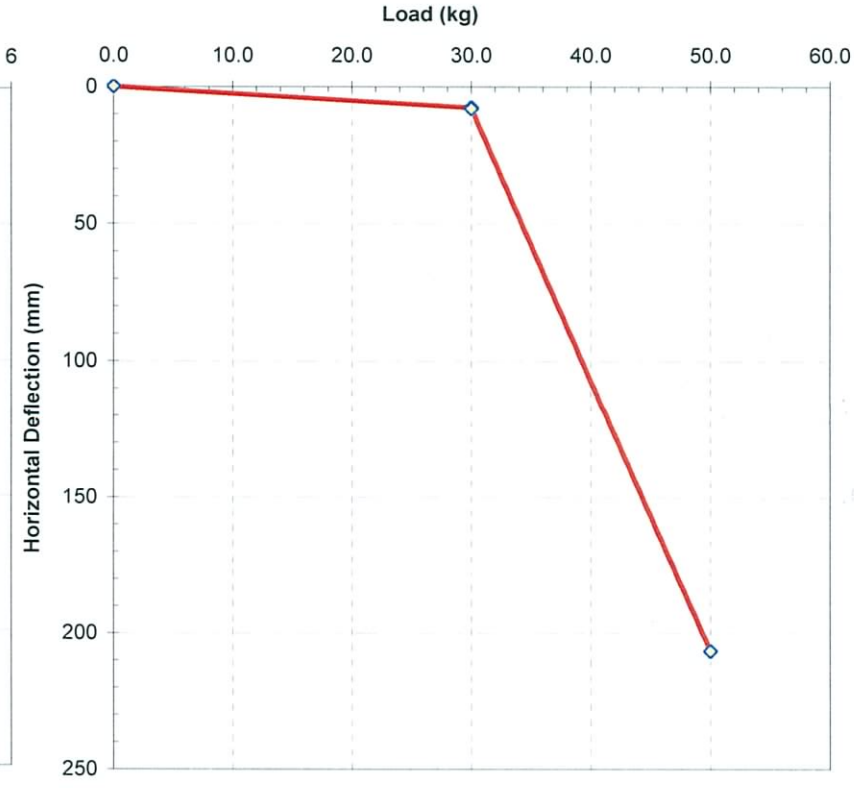
Horizontal Load Test Results

Soil Type & Condition:	Loose sand	Test No:	5
Weather & Temperature:	Sunny 30 C		
Test Type:	Driven pin at front of load frame		
Notes:		Test Date:	30-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



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Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**5A**

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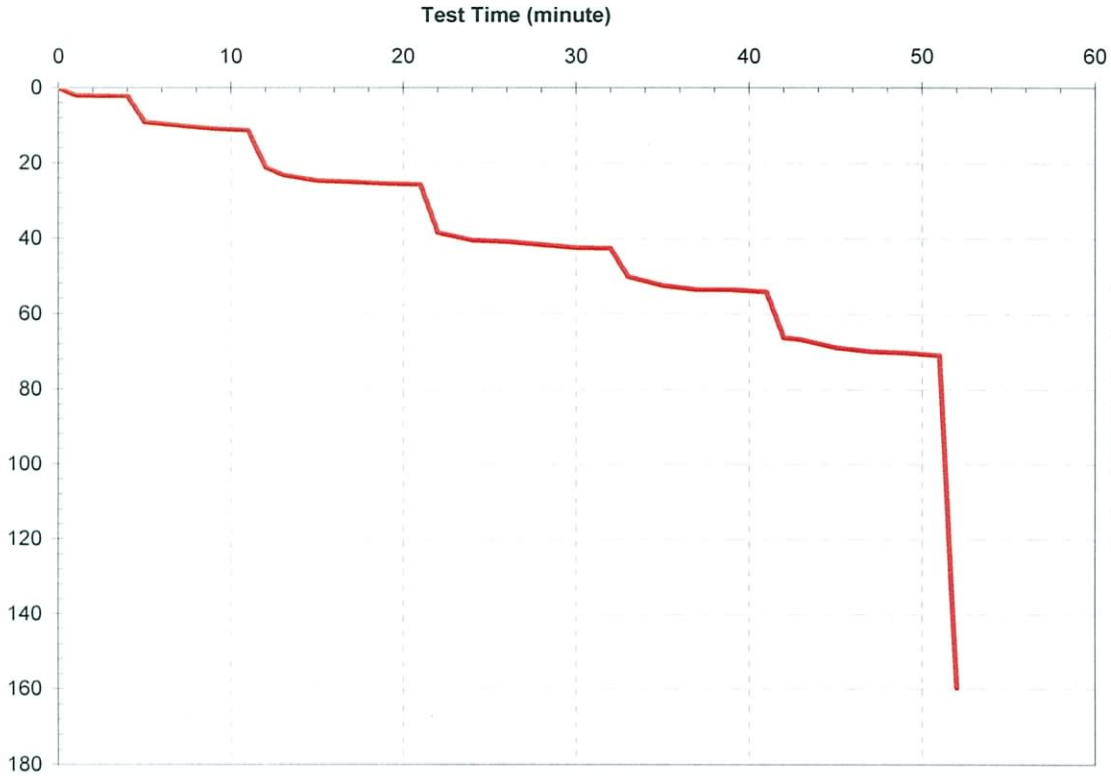
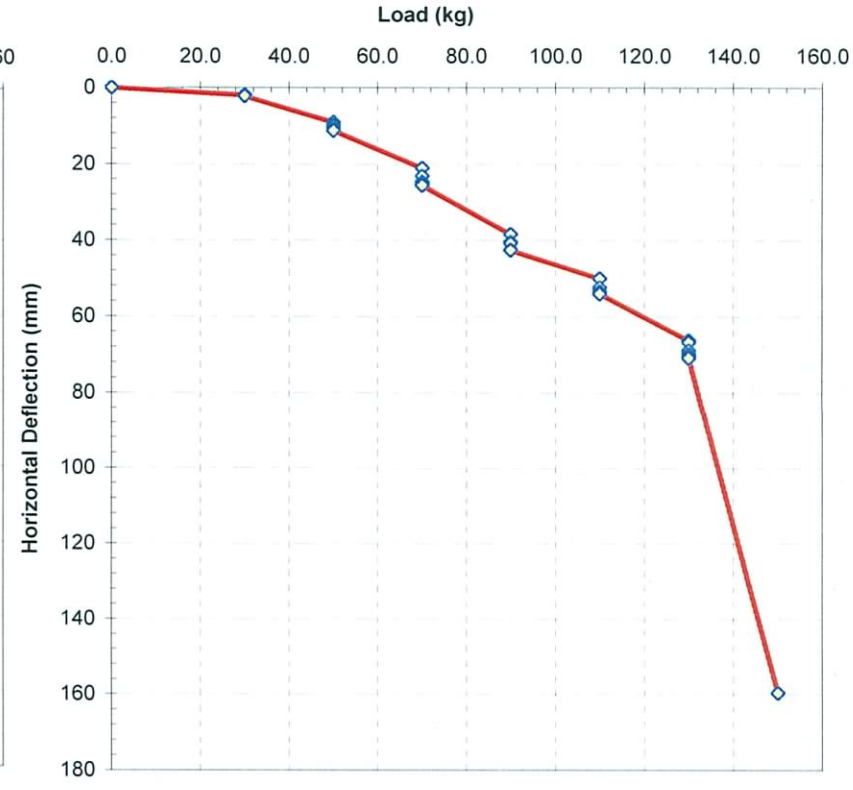
Horizontal Load Test Results

Soil Type & Condition:	Loose sand	Test No:	6
Weather & Temperature:	Sunny 30 C		
Test Type:	18" Pylons		
Notes:		Test Date:	30-Jul-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



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Client:	C J Thorne	**Date:**	13/Aug/2008	**Figure No:**	**6A**

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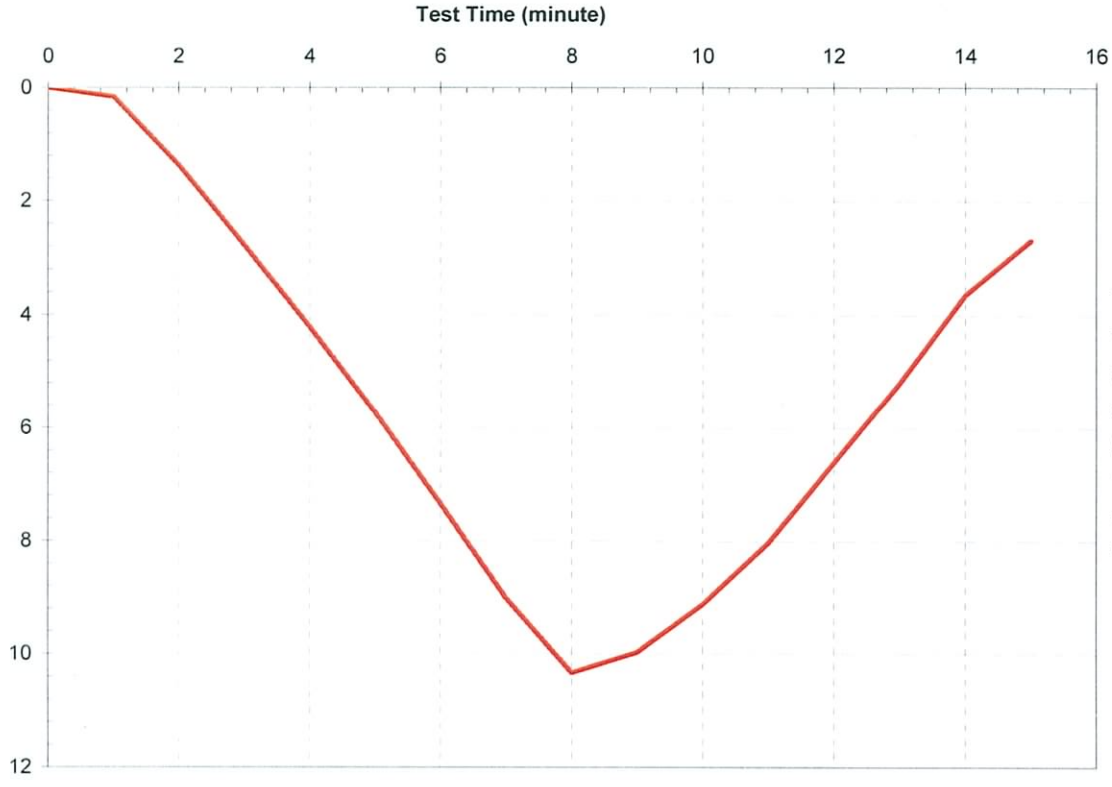
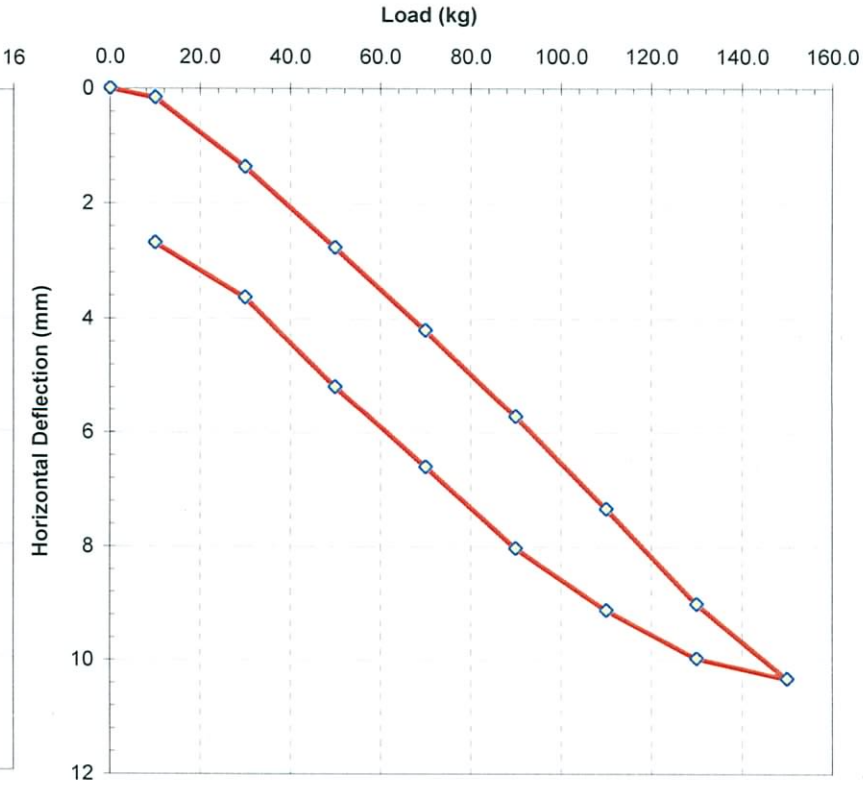
Horizontal Load Test Results

Soil Type & Condition:	Anchored to concrete	Test No:	Rig
Weather & Temperature:	Laboratory, 25 C		
Test Type:	Load Deflection Correction for Frame		
Notes:		Test Date:	07-Aug-08

Horizontal Deflection *vs* Test Time



Horizontal Deflection *vs* Load



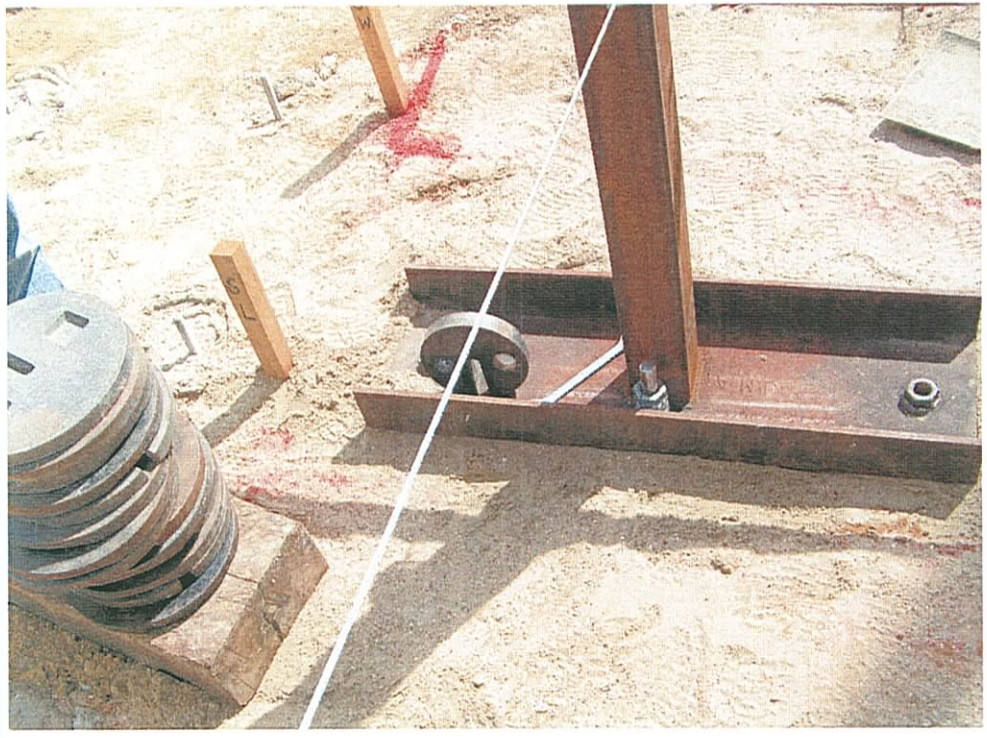
Site:	Union Point, Uckfield TN22 5SS	**Job No:**	J9676	**Checked By:**	
Client:	C J Thorne	**Date:**	11/Aug/2008	**Figure No:**	I

Headstone Lateral Stability Tests

Photograph showing test area with "Pylons" Installed

Photograph showing setting up Test

Headstone Lateral Stability Tests

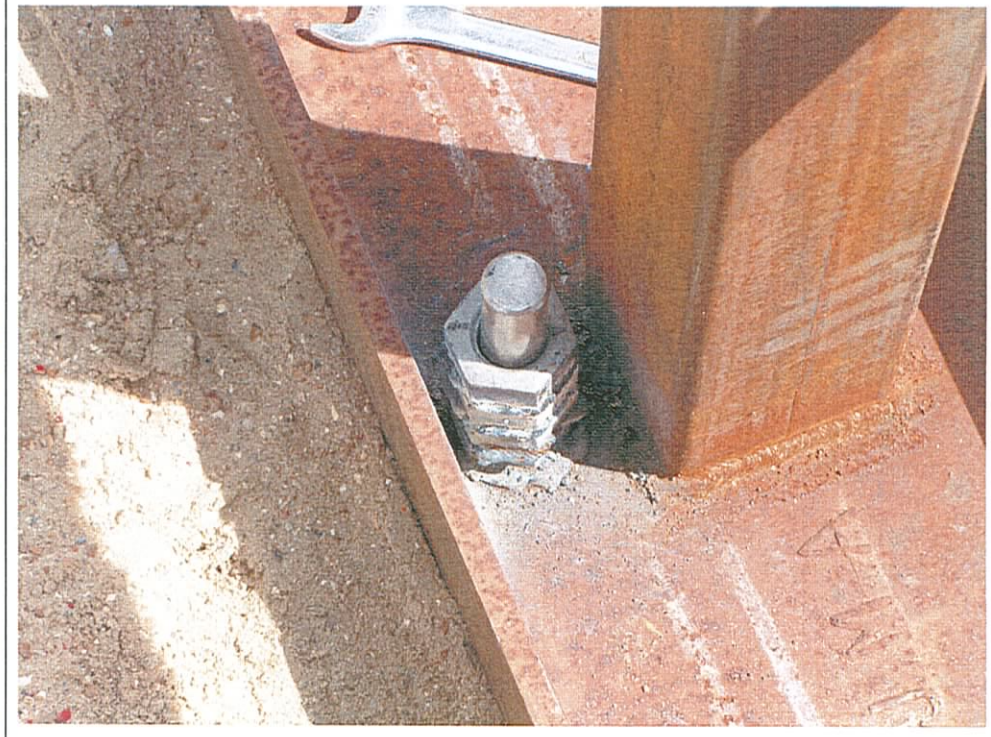


Photograph showing setting up Test

Photograph showing hanger and weights to apply horizontal load

Headstone Lateral Stability Tests

Photograph showing setting up "Pylon" Test



Photograph showing setting up "Pin" Test

Photograph of "Pylon" Test in Very Loose Sand at Failure

Photograph of "Pin" Test in Very Loose Sand at Failure