Reliability in the testing and assessing of piling work platforms

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Introduction

There have been several instances on construction sites of piling rigs and cranes of various types toppling over while operating on un-bound or weakly-cemented working platforms.

The current method of designing piling platforms in the UK identifies that the key problem is "punching failure", but relies heavily on modelling assumptions and on site investigation data. In order to certify working platforms at present a few plate load bearing tests are carried out, and unless there are visible problems the test results are usually accepted without question. As a result, just about any platform passes. The relationship between the data from such testing and the design assumptions is uncertain. The method is also slow and laborious and ties up heavy plant so it is unsustainable to carry out many tests across a platform.

Most significantly, investigations following rig and crane toppling incidents have often found that inherent, isolated areas of weakness or ground collapse beneath a working platform have been the actual causes of failure, which were not indicated by load testing. For this reason, it is essential that contractors constructing such platforms carefully inspect and check sub-grades for any evidence of localised weak areas, such as old pits or trenches.

The intent of this paper is to propose a safe and sustainable protocol for making adequate platform assessments, by:

- Identifying a non-destructive means of rapidly surveying a platform so as to identify any buried anomalies, including defects and reductions in layer thickness.
- Identifying a reliable but more rapid, representative and simple method of load testing a platform, to permit the carrying out of many such tests as opposed to only one or two.

Detection of hidden anomalies

It is possible for hidden "soft spots" and other voids and defects, such as layer thinning, to be present beneath working platforms. Scanning with ground penetrating radar (GPR) is a geophysical method using radar pulses to image the subsurface by detecting variations in the dielectric constants of materials in the ground. To investigate whether GPR could be a reliable alternative to static load testing, trials with modern non-specialist equipment were carried out on two sites.

First, attempts were made to find and map reinstated trial pits located within a piling rig plant yard (Figure 1). Second, a dimensioned traverse was made along a roadway containing visibly-reinstated service trenches.

At the first site four trial excavations, which were hidden »

Figure 1: Attempts were made to find and map reinstated trial pits located within a piling rig plant yard

« beneath a thickness of unbound granular material, were searched for and were mapped with a degree of accuracy of within 300mm.

At the second site, the service trenches under the roadway showed up on the radar plot and a length of significant disturbance in the underlying ground was clearly visible (See Figure 2).

Rapid load testing on working platforms

Static plate load testing

There are some significant differences in approaches to plate load testing. Although such tests have been carried out in various shapes and forms for many years, the rigour by which they are specified is variable.

There are different published standards for carrying out a plate load test compared to a test on a soil sample in the laboratory where there is reasonable consistency in standards. The German DIN Standard method for plate load testing is more specific than the British Standard and defines a "strain modulus" (Ev) but the manner by which it is defined is somewhat anomalous.

Two cycles of loading are specified in the DIN Standard, and as a result two Ev values are defined, being Ev1 for the first load cycle, and Ev2 for the second. Some common ground does exist, since the "modulus of sub-grade reaction", k_{762}, is also defined and specified in the DIN Standard and is defined in a similar way in Volume 7 of the Design Manual for Roads and Bridges (8) in the UK.

Lightweight deflectometer (LWD)

LWDs are not a recent innovation and have been available as portable instruments for a few years in mainland Europe and are designed for assessing the strength of sub-grades and elastic moduli of pavements.

A German 10kg drop-weight LWD was used in these trials. Similar to the static plate load test situation, there are several variations on the LWD equipment and test method. Therefore it must be appreciated that such variations may impact on attempting to evaluate real ground conditions.

The LWD used was actually a type of plate load test, whereby a force pulse was generated by dropping a mass onto a spring assembly that transmitted the load pulse to a 300mm diameter plate resting on the material/ground surface under test.

The resulting deflection of the plate/ground system was measured automatically. Three drops were carried out as part of the standard test procedure and the instrument read out the deflection as an empiric parameter s/v and produced a value, known as Evd, which is the dynamic modulus of the ground/pavement as tested.

Site trials

Site trials were carried out during the period from January through March in 2012.

This testing was carried out on four separate sites at different locations in England. These different sites are designated 1 to 4. Site 1 was located south of Newark, site 2 was located in Lancashire, site 3 was in Birmingham and site 4 was located in Oxfordshire.

At site 4 the exposed clay sub-grade was tested during a first visit and the working platform was tested during a second visit.

A single trained and experienced engineer/technician carried out all the testing.

A 610mm diameter test plate was used as the standard for all of the testing except for a comparative 300mm plate test at site 1.

The resultant data is given in Figure 3.

Relationships derived:

Modulus of sub-grade reaction
$k_{762} = 0.706Evd + 20.230$

Elastic modulus for constrained soil modulus
$Es = 0.774Evd + 17.670$

German modulus as interpreted herein
$Ev1 = 1.267Evd + 58.138$

Settlement at 350kPa on 610mm plate
$S = 29.165 - 0.377Evd$

$CBR = 0.176Evd + 4.99$

Product-moment correlation coefficients were all in the range 0.74 to 0.76.

Summary and conclusions

The greatest risk of causing punching failure through a platform and rig toppling is the presence of voids and defects beneath the platform.

It is apparent from the trial work that GPR equipment might be easily deployed to site and used by a non-specialist engineer/technician for a more targeted and relevant assessment of piling platforms.

It is therefore proposed that GPR should be used prior to arrival of plant to site to identify any apparent buried anomalies, so that any such locations can be load tested with LWD and exhumed where necessary.

The static plate load test method is potentially uncertain and unreliable. It is generally not well understood as an assessment method and is loosely defined as a test, and hence used minimally in interpretation for risk assessment and compliance. Whereas several data points generated in the LWD tests gave more information and some consistency and correlation could be noted across the data for specific sites, with "apparent strong or weak" anomalies standing out.

It is suggested that LWD testing is a more reliable and sustainable approach for load testing platforms and that reliance on plate load testing is reduced or even abandoned. Since the UK industry is familiar with the type of information produced by static plate load testing relationships, it could be used to generate similar information from LWD testing. Such an approach would be in line with the simplified procedures often employed to design working platforms and the

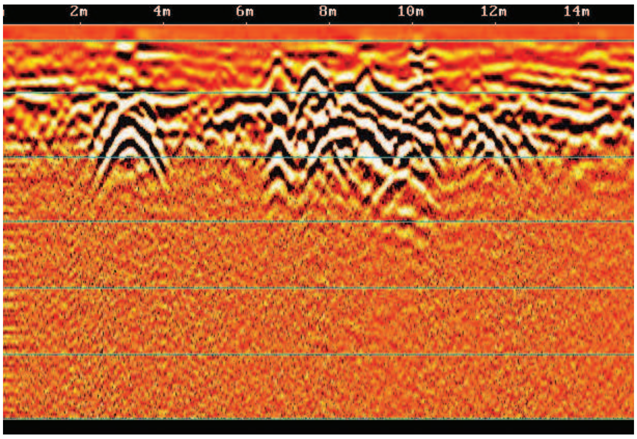

Figure 2: A length of significant disturbance in the underlying ground was clearly visible from the radar plot

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Figure 3: Analysis of plate bearing date

	Cycle 1						Cycle 2					
Test location/ ID	**k_{762} (MPa)**	**Es (MPA)**	**Ev1 (MPa)**	**Deflection at 350kPa (mm)**	**CBR (%)**	**Evd (MPa)**	**k_{762} (MPa)**	**Es (MPA)**	**Ev2 (MPa)**	**Deflection at 350kPa (mm)**	**Evd (MPa)**	**Selected for analysis**
Site 1, Area 1 300mm plate	274.1	441.2	652.2	0.77	69	78.48	1,370.48	–	6,000.0	0.06	78.48	
Site 1, Area 1 610mm plate	81.2	58.1	63.2	4.94	17	78.48	168.9	129.0	276.9	2.36	78.48	X
Site 1, Area 2 610mm plate	68.9	76.9	173.1	4.56	17	45.45	148.9	124.2	211.8	2.29	45.45	X
Site 2, Test 1 610mm plate	<21.8	7.2	12.4	36.93	<5	18.49	–	–	–	–	18.49	X
Site 2, Test 2 610mm plate	144.4	145.2	450.0	1.99	36	18.49	129.2	148.1	290.3	2.39	18.49	
Site 2, Test 3 610mm plate	26.9	20.2	49.2	17.88	7	18.49	22.5	66.2	233.8	8.79	18.49	X
Site 2, Test 4 610mm plate	78.7	57.8	131.4	5.23	20	18.49	52.6	77.5	200.0	4.71	18.49	
Site 3, Test 1 610mm plate	106.8	105.3	327.3	3.03	27	45.86	335.3	384.6	900.0	0.82	45.86	
Site 3, Test 2 610mm plate	127.0	190.5	418.6	2.11	32	45.86	841.2	1,111.1	2,571.4	0.42	45.86	
Site 3, Test 3 610mm plate	79.8	45.1	125.0	6.04	20	45.86	111.9	143.9	367.3	2.52	45.86	
Site 3, Test 4 610mm plate	75.3	79.4	189.5	4.25	19	45.86	251.6	370.4	900.0	1.14	45.86	X
Site 4, Test 1 610mm plate	105.6	35.8	38.9	6.63	26	4.39	224.3	131.6	257.1	2.09	4.39	
Site 4, Test 2 610mm plate	45.6	98.0	246.6	4.40	11	58.59	278.0	270.3	692.3	1.01	58.59	X
Site 4, Test 3 610mm plate	37.2	109.9	339.6	5.38	9	13.20	122.0	133.3	321.4	2.49	13.20	
Site 4, Test 4 610mm plate	50.7	34.7	83.7	8.96	13	66.96	357.1	370.4	900.0	0.75	66.96	X
Site 4, 27/03/12 610mm plate	123.1	52.4	124.1	4.39	31	20.95	122.3	136.1	285.7	2.53	20.95	

Figure 3 Notes
a) "Cycles" refers to parameters determined on the first or second cycle. b) "k762" refers to the modulus (or coefficient) of sub-grade reaction. c) "Es" refers to the secant elastic modulus (without correction for Poisson`s Ratio) from 150 to 350kPa in the 610mm plate tests carried out (with no size conversion) d) "Ev1 and 2" refer to the secant elastic modulus (without correction for Poisson`s Ratio) from 135 to 315kPa in the 610mm plate tests carried out (with no size conversion), on the first and second cycles respectively. e) "Settlement at 350kPa" refers to the mean plate settlement recorded at a load of 350kPa under a 610mm diameter plate .f) "CBR" refers to the equivalent theoretical California Bearing Ratio as calculated from the relevant k762 g) "Evd" as given in blue and repeated is the dynamic modulus as generated by the LWD instrument. h) The data points marked with a green cross under "Selected for Analysis" are the data points considered to be most representative/least anomalous herein as used in linear regression.

various assumptions made in taking this approach.

It should be noted that the need for kentledge does not limit the use of the LWD and it is suggested that it is better to carry out many tests across a platform to check and validate the stiffness of the as constructed platform. Determining the dynamic modulus in a manner that allows less opportunity for operator error through use of a repeatable and reproducible method is considered to be more beneficial than carrying out fewer, more costly plate loading tests, which are heavily operator-dependent and difficult to interpret with certainty.

As a result of the testing, the following protocol is proposed:

1. Check the available site investigation reports to determine whether the platform area is or was underlain by organic soils or other obviously suspect ground type or condition (such as shallow mine workings). Are there any? Yes/No

Stop and do some site investigation if no information is available.

If the answer to question 1 is "yes" then a detailed risk assessment needs to be undertaken prior to the start on site.

If the answer to question 1 is "no", go to 2.

2. Carry out a GPR survey across the whole site as a first step to assessing the platform. Identify all buried anomalies and decide which require further investigation, and physically mark these on the ground and plot on site drawings.

3. Carry out many LWD tests across a platform, being as minimum one per $10m^2$ area and test all anomaly locations as identified by the GPR or other surveys.

4. Consider s/v values obtained from the LWD and when more than 5% of values exceed 4.5, the platform should undergo further compaction with suitable plant and then be re-tested.

5. Check that the mean Evd (dynamic modulus) of all values where s/v does not exceed 4.5 is at least 20MPa and that there are no locations where such values are less than 15MPa.

6. Issue a Certificate of Platform Assessment for the platform giving Pass/Fail based on the recommendations above, along with any requirements for further investigative and remedial action.

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