

SCREW PILING INFORMATION SHEET

BRIDGE FAILURE AVERTED



Background

A bridge contractor engaged a screw piling contractor to install 50 tonne piles for two bridge abutments and two intermediate span supports. The piling contractor commenced installing the piles without any geotechnical report, test piles or static load testing.

The piles were installed to 6m deep and preparation commenced for the headstocks.

Engineer Concerned

The piles were installed to the installation torque of 50,000Nm, erroneously in the belief that it equated to 500kN Safe Working Load. The contractor terminated the piles at 6m deep once this torque had been achieved.

The council engineer was concerned with the situation and contacted P.J.Yttrup and Associates who are one of the leading authorities on screw piling engineering in Australia. Peter Yttrup recommended CPT testing be conducted urgently.

CPT Results

A probe extract is shown to the right.

As the CPT result shows the piles were terminated at 6m depth in medium dense sands only 300mm above a much softer layer. It would be likely the piles installed to 6m would have punched through to the soft material, causing settlement issues and possible bridge failure.

On reviewing the CPT results P.J.Yttrup and Associates recommended that the piles be installed to 12.5m with 100,000Nm of torque.

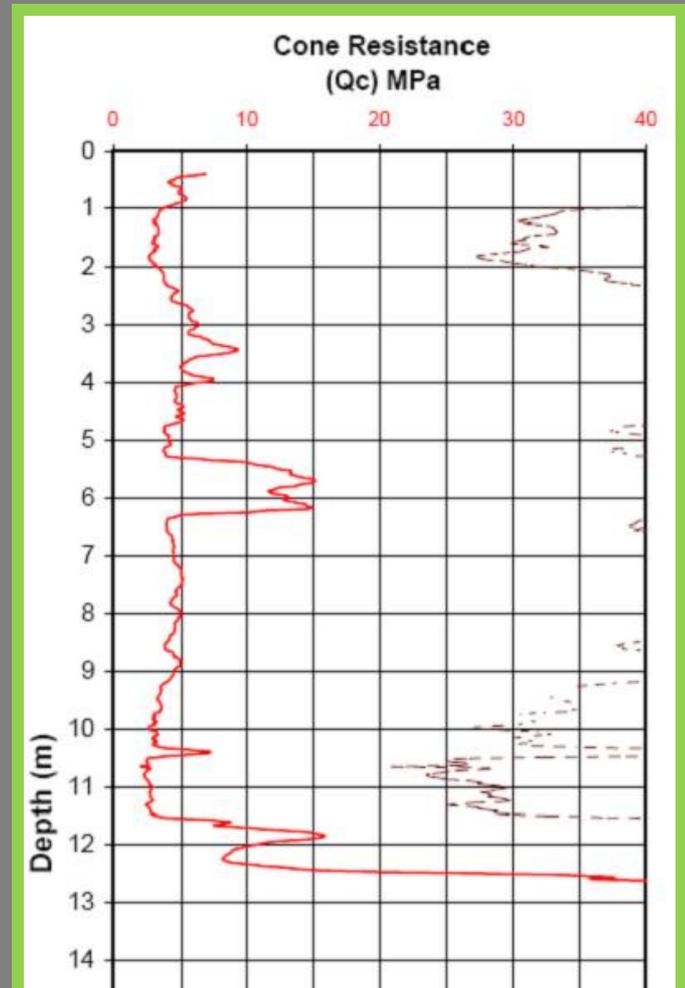
We were engaged to install the piles deeper to 12.5m plus depth and 100,000Nm, as the original piling contractor only had a 50,000Nm capability.

This is how a likely bridge failure was averted.

Recommendations

We are happy to recommend geotechnical investigation firms with different capabilities to match the specific project requirements or conduct these ourselves. These capabilities range from CPT, to SPT and seismic investigations.

CONE PENETROMETER TEST RESULTS



This graph shows a medium dense layer at around 6m, below which is soft soil until around 12.5m which is good founding material. Information used with permission from P.J. Yttrup and Associates who can be contacted on 03 5243 3388 or admin@yttrup.com.

We Can Help You

If your project has piles specified we are happy to provide you with a competitive price. We are confident that our price will be cost effective when compared directly on a like for like basis.

We do not compromise the pile design by using questionable engineering practices.

We have extensive load testing experience and results have been correlated to our pile design program.

Russell Heale Screw Piling

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SAVING MONEY? COSTS BIG!



Builders are often driven by the lowest price and try to save dollars by commissioning only the most basic geotechnical investigations and employing the cheapest piling contractor. In the following example the building settled unevenly up to 150mm due to the inadequate soil test and questionable screw pile engineering.

Relying on Torque Only

The piling installation was based on torque alone with a very shallow geotechnical report and no test piles or static load testing. The piles had been installed to a predetermined torque, which equated the torque required to the load required as a 10 to 1 ratio. The piling contractor mistakenly believed he had achieved pile set.

Piles not deep enough

The piles were terminated at a depth of 14m at the torque nominated. Subsequent geotechnical investigations show that the piles were terminated 4 m short of adequate founding material.

Reverse computations have demonstrated that the shaft friction contributed significantly to the total torque and that the torque contribution at the helix was minimal.

The project engineer asked us what could be done to correct the failure of the piling installation by the piling contractor. Our answer was that it was too late. The building is still standing but the settlement issues will probably mean at some point it will have to be demolished and rebuilt.

Avoid Disaster

The project engineer should review any proposed pile design prior to on site installation.

We often see pile designs utilising pile shaft sizes that are inadequate for the specified load and the necessary installation torque required.

Our pile designs are often justified with on site load testing and the testing benefit factor used to make the pile design as economical as possible yet compliant with AS 2159-2009 piling code.

We are also happy to recommend geotechnical investigation firms with different capabilities to match the specific project requirements or conduct these ourselves. These capabilities range from CPT, to SPT.

2D Diagram shows pile founded 4m before rock

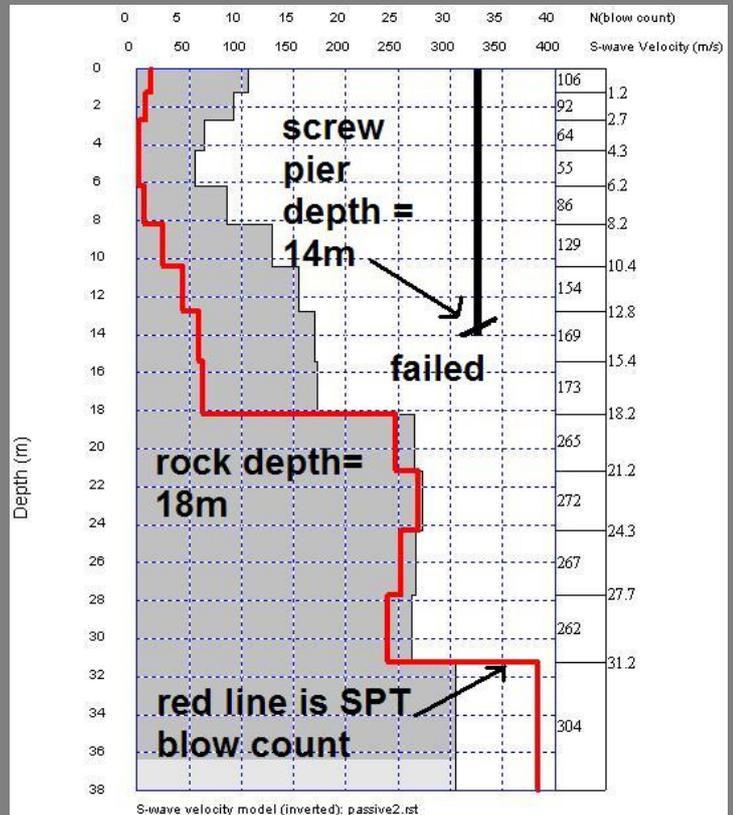


Photo of finished building with uneven settlement up to 150mm.

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CRANE BASE CASE STUDY



Water Main Crane Base

One particularly interesting job that we have done was the crane bases for an 1100 tonne crane that had a lift of A 200 tonne bridge span for a water main.

On establishment the crane company realized that the ground conditions were not suitable. A phone call to us very late one Thursday afternoon explained the problem and the urgency set the wheels in motion. Fortunately there was an extremely good geotechnical report available which indicated excellent founding material at 12 metres deep.

Pile Design

We did an initial pile design and outlined the costs on the Friday. After approval late Friday afternoon from the client, our engineers spent the weekend refining and finalizing the pile and the pile cap design, on the four 6.5 x 6.5 metre pile caps for the outriggers of the crane to sit on. Loadings for each pad were in excess of 3100kN. As there was a requirement for minimal settlement we decided on 9 piles per pile cap.

Although the client wanted the structure for only one lift they also wanted it to be permanent so that it could be utilized at any time in the future if a parallel line had to be installed.

We used bearers and joists over the piles which were designed to transfer the weight in total to the piles. The pile caps could have been used without the concrete if the client had wanted the piles removed.

Great Result

The following Thursday the crane was in place to do the lift. The lift proceeded with a surveyor with 2 way radio contact with the crane driver.

As the crane was to be working at 98% of its capacity there were concerns for the stability of the crane. As the lift proceeded all four foundation pads were monitored and a maximum of 1mm deflection was noted. This minimal deflection enabled the crane to complete the lift 6 hours quicker than was scheduled.

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Photo Gallery for Crane Base Installation



Installation of piles progress as other pile caps are prepared for concrete pouring.



Pile cap prior to pouring of concrete.



Lift under way. Notice the massive counterweight that was lifted only a few millimetres off the ground. The dogman on the far side of the river is visible.

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HELIX INTERACTION



Helix Interaction

As a result of our load testing we have observed the deflection of the helix plate to varying degrees. Where we have wanted to determine the geotechnical capacities without structural failure being an influence on the results we have utilized thicker helix plates.

Over the past few years there has been a far greater understanding of the helix/soil interaction. Extensive load testing has been undertaken to specifically look at various aspects of the screw pile behaviour.

We have carried out our own series of load tests investigating the effects of differing helix pitch. The test shown to the right indicated that for identical piles with differing helix pitch, differing loads will be achieved.

Further testing was carried out installing piles with helixes of different pitch to different torques to achieve the same loadings. It demonstrated that the torque required is different depending on the helix pitch.

Some of the findings of the research by P.J.Yttrup & Associates Pty Ltd, Consulting Engineers is summarised below from their paper "Steel Screw Pile Installation and Design";

The structural strength of the helix can limit the base resistance that can be mobilized at the base of the pile. The ultimate base resistance of steel screw piles is governed by the simultaneous geotechnical and structural failure at the helix. Ground displacement occurs simultaneously with bending of the helix plate.

For "strong" helix plates the base resistance is geotechnical, for a "weak" helix the plate yields and deforms plastically. The helix design is an important part of the screw pile design, and is different to other piles.

For specific information on helix pitch please contact us or P.J.Yttrup & Associates Pty Ltd in Geelong, VIC.

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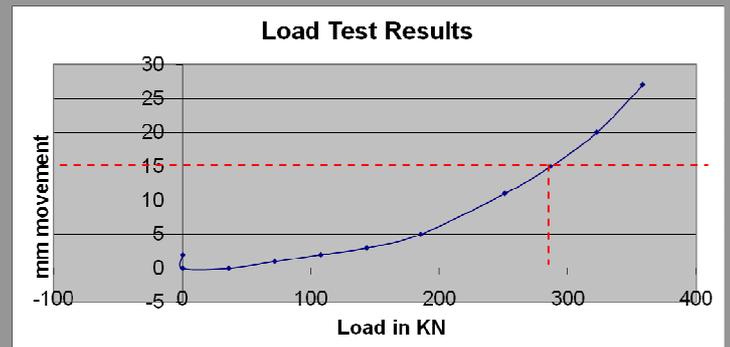
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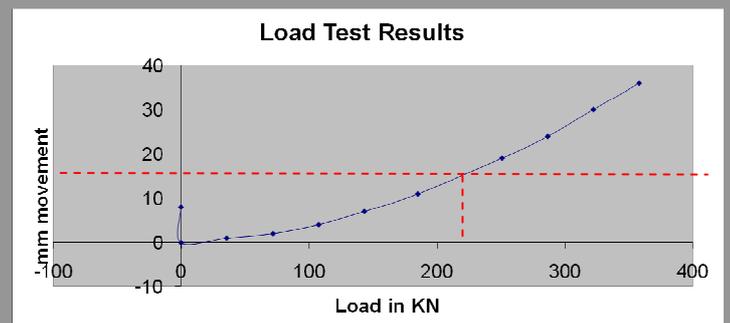
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Helix Pitch Comparison Load Tests

Two load tests were conducted with identical pile sizes installed to the same torque, only the helix pitch was different. One had a 70mm pitch and the second a 100mm pitch.



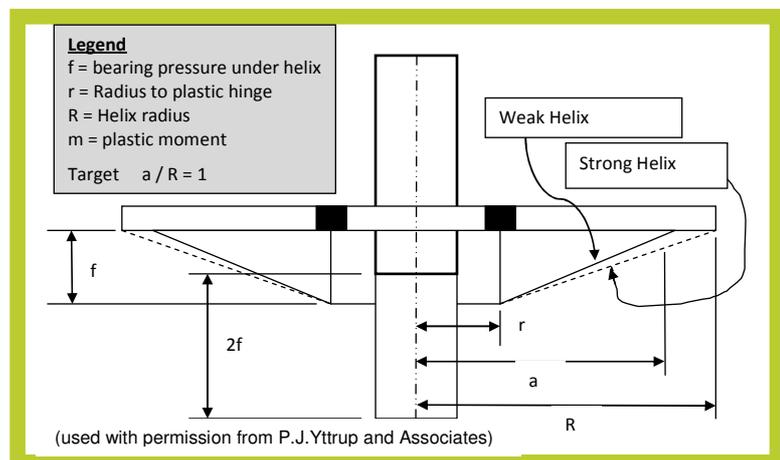
Pile 1



Pile 2

The load capacity is quite different showing that helix pitch is an important factor.

Please note that the above data is an example only.



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TORQUE MEASUREMENT



Accurate Torque Measurement System

The Torqatron is a load cell calibrated to measure torque with an excavator mounted digital readout.

Russell Heale has been involved in the screw piling industry since 1995 and is always striving for improvement through research and development. One important area of progress is in the current calibration and torque measurement procedures and the development of the innovative Torqatron system.

We are the only Australian manufacturer of load cells for measuring torque for screw pile installation, with a test bed for calibration up to 500,000 Nm

Calibration

The load cells manufactured at Russell Heale Engineering are individually calibrated to their own readout and have to be calibrated to work. The strain gauges in the load cell are fitted by an expert in this field. They are calibrated to the minimum and maximum torque and then to up to five intermediate set points. The whole process is repeated 5 to 7 times to ensure that repeatability is well within the specified range. The test bed has NATA certified force measuring equipment fitted. The repeatability has been found to be around the 0.2% range. Our units are recalibrated every 6 months as required by AS2159-2009 Section 7.3.5.3.2.

Overstatement of Torque

Using other measurement systems we have directly observed errors of up to 50% overstatement of installation torques. We cross checked a 10,000Nm installation which revealed an actual installation of only 5,000Nm. These other methods commonly used for measuring torque are the Bourden pressure gauge and pressure transducer systems which measure hydraulic line pressures to determine torque applied.

With these other measuring systems it is difficult to establish the actual losses of the gearbox or the hydraulic motor, which may vary depending on speed, the torque being applied and the condition of the gearbox or motor itself. This results in an artificially high torque reading and is not obvious to the operator.

In Summary

Of course the reason for using screw piles is to have the confidence that the structure built on the site will be solid and stable for many years to come. It is important to be sure that piles are installed to the torques required to handle the loads asked for. The best way to do this is by using the world's best practice torque measurement system, the Torqatron.



Benefits of Torqatron Load Cell

There are huge advantages of using a Torqatron;

- Actually measures torque not hydraulic line pressures
- Repeatable
- Easy for operator to use, only one gauge to monitor
- False readings obvious to operator as shows as an error on digital readout
- Accurate every time
- World best practice



Issues with pressure transducer or a Bourden pressure gauge system include;

- Usually does not account for constantly changing return line pressures
- Hydraulic, internal or gearbox losses impact on reading
- False readings not obvious to operator
- Cheaper versions are impacted by vibrations generated by machine
- Limited life

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LARGER LOADS



Demand for Larger Loads on Piles

Initially screw piling was used for smaller loads up to 200 kN, but progressively the demand has been for larger loads to the point where loads of over 150 tonne SWL and beyond are achievable.

There is a theory used by some in the industry that 10,000 Nm of installation torque equals 100 kN of axial capacity. This may be roughly correct at 5000 Nm but it is certainly not correct at 100,000 Nm, and less so at 200,000 Nm. Static load testing has proven this.

Different Soil Types

There are differences between soil types, sand and clay. The installation torque required for a given load may in fact be different for clay soils to that required for sand. See the example to the right.

Compression and Tension Piles

The torque required also differs for compression piles and for tension piles. The helix pitch and size along with tube size and length also impacts both the torque required and the load capacity of the pile.

That 100 : 1 relationship often quoted is in fact a variable number and goes up beyond 300 : 1 as the pile loads increase, i.e. the torque required to carry a given load may need to be significantly higher than expected.

Combining the axial load, any additional negative skin friction loads and the shaft generated torque, the resultant torque required may be significantly higher than expected for the pile performance to comply with AS 2159.

Effects of Length and Diameter

The length and diameter of the pile have a direct influence on the torque generated by the pile shaft. Obviously a very short shaft has a small amount of shaft adhesion, requiring only a small amount of torque to overcome resistance. A very deep pile can have a very significant shaft resistance generated. It is not impossible that up to 80,000 Nm is generated by a very deep, larger diameter shaft.

The pitch of the helix impacts on the torque required, and has an impact on the settlement characteristics.

Stress from Installation Torque

One of the greatest stresses that the screw pile can be subjected to is the installation torque. This installation torque is often the determining factor in selecting tube size.



Clay Site Example

An example of torque required, for a given clay site, with very short piles may be as follows;

<u>Loads</u>	<u>Torque required</u>
50 kN	6,100 Nm
100 kN	12,200 Nm
200 kN	24,350 Nm
300 kN	41,750 Nm
400 kN	69,600 Nm
500 kN	87,000 Nm
600 kN	125,000 Nm
700 kN	146,000 Nm
800 kN	195,000 Nm

Sand Site Example

In contrast a sand site with much longer piles, 9m, could require significantly more torque.

<u>Loads</u>	<u>Torque required</u>
50 kN	12,700 Nm
100 kN	18,200 Nm
200 kN	33,750 Nm
300 kN	54,500 Nm
400 kN	80,500 Nm
500 kN	126,000 Nm
600 kN	142,000 Nm
700 kN	177,000 Nm
800 kN	240,000 Nm

Please note that the above data is an example only and will vary depending on site geotechnical conditions, the geotechnical reduction factor applied, tube diameter, pile depth, helix diameter and pitch.

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LOAD TESTING & MOMENTS



Load Testing

We have conducted in excess of 200 load tests and P.J.Yttrup & Associates Pty Ltd, Consulting Engineers have over 1,000 results. This has improved our understanding of the effects of different types of soil conditions, helix pitch and torque.

Methodology

All of the load tests we have conducted have been static load tests using the incremental sustained load method, as described in AS 2159- 2009 Piling Installation and Design. Most have gone on to test the pile to failure on completion of the test as laid out in AS 2159, so that the ultimate capacity is determined.

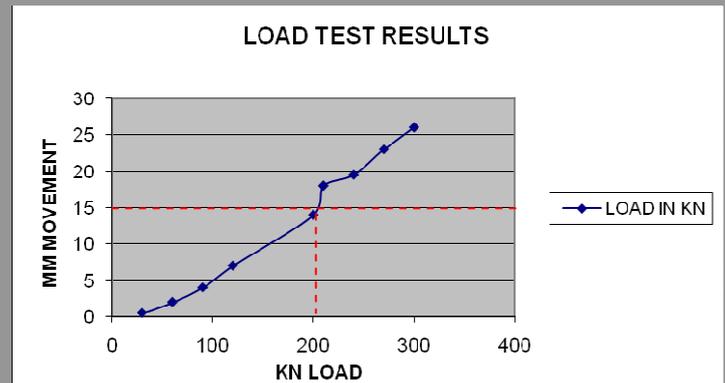


In order to minimise on site disruption, an additional pile can be installed on site for testing purposes. That way the builder can proceed with his construction program with minimal interruption.

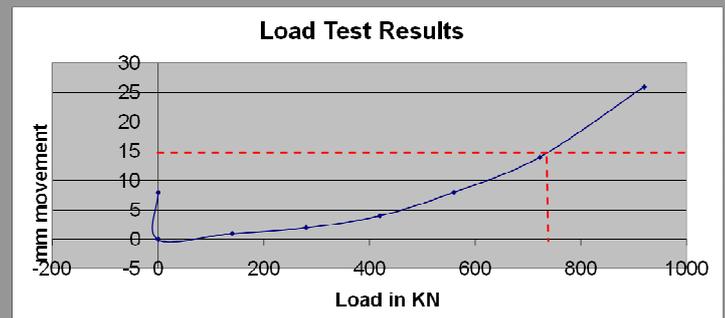
Where possible we prefer to conduct load testing prior to construction, as the results may assist refining and optimizing the pile design.

Load Test Results

The following load test is the result of a test done in sand. The pile was installed to 70,000Nm and load tested to prove that 70,000Nm did not equate to 700kN axial capacity.



Pile Test 1



Pile Test 2

The pile was then installed to 167,000Nm and then load tested, showing this torque achieved the required loading of 700kN.

Please note that the above data is an example only.

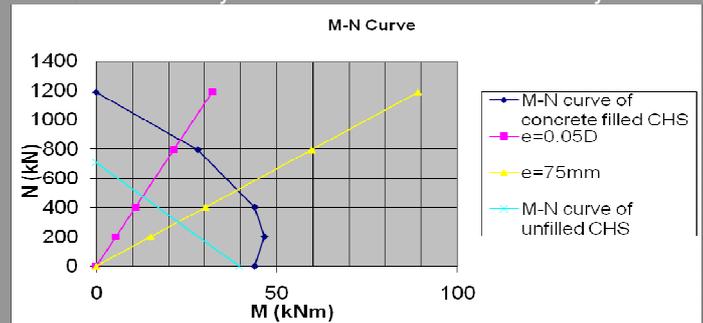
Moment Load

Another stress a pile tube can be subjected to is the eccentric moment. AS 2159 stipulates the pile should be considered for 75mm eccentricity.

There are significant advantages in using concrete filled piles, which are capped at the bottom, in terms of increasing axial capacity as well as protection against corrosion.

Moment Curve Example

This M-N CURVE is for a 168 X 6.4 tube with 0.03 mm corrosion over 50 years with external corrosion only.



Assuming there is a N^* load of 371kN, the moment will be 27.85 kNm. Using the above graph the pile will need to be concrete filled. (32mpa used in this example).

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SOIL TEST REQUIREMENTS



Classifications

If the soil is classed as suitable for high level footings then the report is probably adequate and useable for a footing design. If the soil is classed as 'P' or incapable of supporting high level footings, then the report will probably recommend deep foundations.

Thin or Thick Layers

The sub-soil types seen by screw pile installers in S.E. Queensland on the Gold and Sunshine Coasts are often many different layers of sands and clays or mixtures; sometimes interspersed with very thin, but hard layers of cemented sands or shells.

Sometimes a report may identify a very dense layer for the piers to found close to the surface; but often will not clearly identify that a deeper investigation is needed. It causes grief to many builders using deep foundations when they end up much deeper (and more expensive) than expected.

We can torque up a screw pile in a dense layer until it meets its torque requirement and appears to satisfy the SWL requirement. It may be possible to found the piles in that layer if it is several metres thick. But if it is sitting 200mm above a soft layer it can punch through and building settlement occur. Only an expensive static load test will identify that potential problem.

SPT or CPT

Actual SPT or CPT results are required to accurately design a piling system.

If a soil report recommends piles and does not identify the soil capabilities for 2 plus metres beneath their base, then a deeper examination may be required. This could mean a continuous CPT probe with Pore Pressure and Sleeve Friction readings or deep Borelogs with SPT testing every metre or an Ne SPT probe..

By spending a small amount of money up front and obtaining a quality Geotech Report, money can be saved on the project in the long run.

Changes to the Piling Code

AS2159 now has more specific requirements for site investigations where piling is proposed (see section 2 of the code). There is now a more specific method of determining the basic geotechnical strength for the job and a formula is given for determining the geotechnical reduction factor where load testing is conducted.

In Brief

- The SPT/CPT results are needed and the larger the pile load; the more important the requirement for SPT or CPT results
- We use the numerical values from your report in design calculations for end bearing capability, shaft adhesion and negative shaft adhesion
- The minimum DCP we look for in domestic construction is 10 blows/100mm

NB: DCP's may not be very accurate in situations where deep probes are made and in some soil types the reading can be misleading due to the sleeve friction.



An example - Broadwater Sugar Mill NSW:

By having SPT results, at the building location, which went some 8m deeper than the final founding depth, we were able to confidently design the piles. The installation process involved torque measurements of all piles every 500mm to correlate the installation with the design.

This resulted in a 35% saving on piling costs on a major project by using a quality report which enabled the pile design to be completed with a high level of confidence.

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