CORRELATION BETWEEN DLT AND SLT - CASE HISTORIES

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ABSTRACT

Due to the increase in service loads of foundations, a world wide trend is being followed by geotechnical engineers and designers to measure the real behaviour of the pile-soil interaction. Historically, this was defined by the Load-Displacement Curve, obtained from a Static Load Test, and the concept of bearing capacity…if those involved in the project arrived to an agreement on its definition. Technology developed and the concept of Dynamic Load Test (DLT) arrived, bringing with it an economic and faster way of measuring the response of piles to imposed loads. But is this what the geotechnical engineer requires?

A comparison between DLT and SLT is analysed throughout the eyes of a geotechnical engineer and not from the perspective of a testing house. Different types of piles were tested with both methods, seeking for correlation, side effects and installation influence in results, aiming to know the real performance vs. predictions.

INTRODUCTION

In the first half of the '80s, it was introduced in Argentina the pile testing speciality based on the Stress Wave Theory; at the beginning through the Sonic Integrity Test (SIT), as a parameter for control quality of foundations and, afterwards, with the Dynamic Load Test (DLT) in order to measure the pile-soil behaviour.

But up to then, how was determined the bearing capacity of a piled foundation? The answer is simple, in the same way than in the rest of the world, that is, with a Static Load Test (SLT). As we all know, in spite the familiarity SLT has within the engineering community…that, if we first agree on what type of SLT, due that the ASTM D 1143-81 Standard has five different methodologies…it is time and money consuming.

During those years, where Quality Assurance (QA) started to play an important role in the Argentinean construction market, as well as the increment in service loads, lead to an increase in the demand for verifying piling works. As well, a reactivation of the local economy, the availability of new technology in construction methods and tighter schedules for finishing site works, allowed the DLT to be introduced as an alternative to the cumbersome static test.

It is the objective of this Paper to present correlations between Dynamic and Static Load Tests performed on the same pile, including all the information that the Geotechnical Consultant had at the moment of analysing the results and highlighting how it was arrived to those conclusions. It is the moment to mention that in all cases the Dynamic Load Tests were performed using the FPDS-3 equipment, developed by TNO Building & Construction Research (the Netherlands), while the SLTs were conducted under ASTM Standard. When the Static test was carried out, the transfer load structure assembled consisted in a beam and reaction piles anchored well below the influence area of the test pile.

CASE HISTORIES.

Buildings

The site was a group of buildings constructed in the City of Buenos Aires, Argentina. The ground conditions are described in the following geotechnical profile (Figure 1), and the pile type was of substitution, reinforced concrete and casted in-situ under bentonite mud (pile characteristics are presented on Table 1).

Table 1. Pile characteristics.

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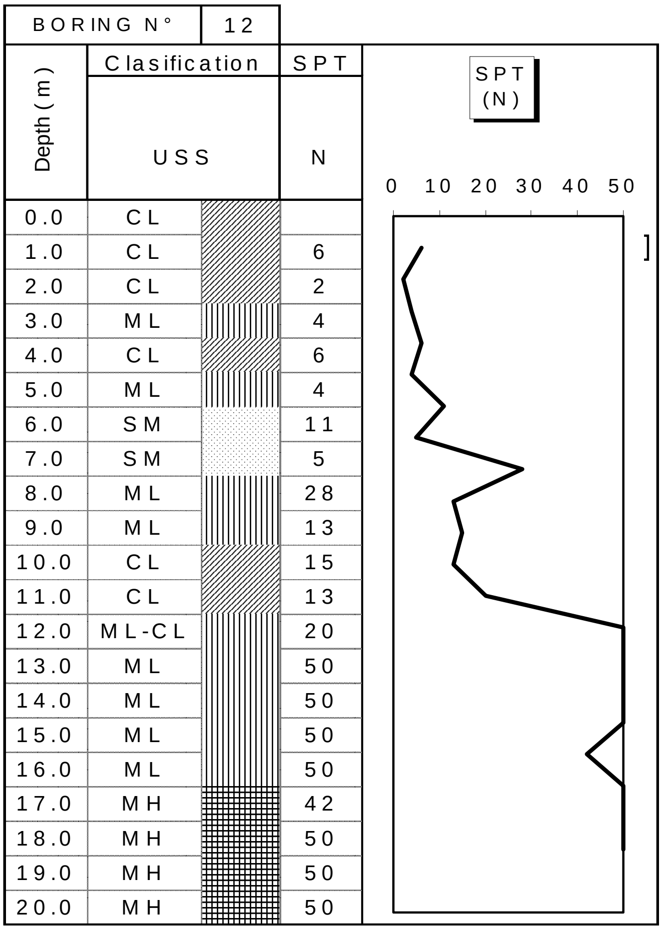
Pile Type	Bentonite mud	Diameter (m)	Length (m)
I	✓	0.35	14.0
II	✓	0.40	15.0
III	✓	0.50	15.0

Figure 1. Geotechnical profile.



The foundation project consisted in 408 piles placed under caps in groups of one, two or three units each. All the installed piles had to be controlled through the Sonic Integrity Test (SIT) in order to verify that they were free of damages and to select which ones were to be subject for DLT and SLT.

It was decided, by the Engineer, that the first three piles were going to be tested statically with the 'slow method' and then 7% of the foundation population (29 piles) were going to be tested with the Dynamic Load Test (the tests information is presented on Table 2)

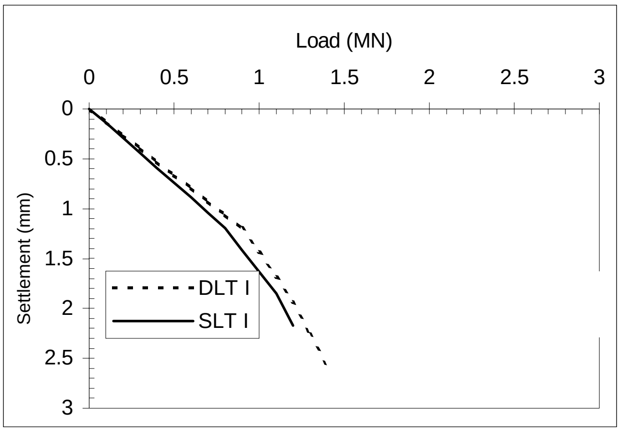
Table 2. Test programme*

Test Type	Pile Type	Quantity	Service Load (MN)	Max. Test Load (MN)	Maximum Settlement (mm)
DLT	I	10	0.6	1.4	2.6
	II	10	0.7	1.9	3.0
	III	9	0.9	2.4	3.9
SLT	I	1	0.6	1.2	2.2
	II	1	0.7	1.4	2.1
	III	1	0.9	1.8	2.6

Note *: information is presented only for those piles where DLT and SLT were performed.

Conclusions: The results of the homologated tests are presented on Figure 2, where it is clearly seen the good correlation between DLT and SLT. The quality of this match depends dramatically on the quality of the geotechnical investigation, the knowledge of the mechanical properties of the concrete and the concrete consumption, in order to check variations in the cross section of the piles.

Figure 2. DLT and SLT load-settlement curves.

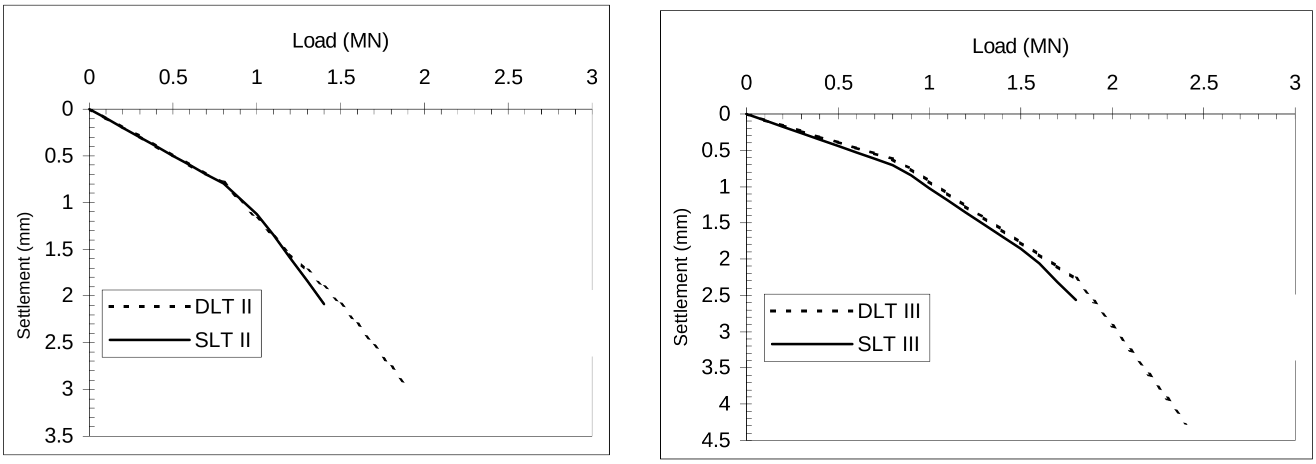


Industrial Facility

The site consisted in the expansion of an industrial facility in the South Area of Gran Buenos Aires, where 250 precast reinforced concrete piles were going to be driven with a diesel hammer. Pile data is available on Table 3.

Table 3. Pile characteristics.

Pile Type	Cross section (mxm)	Length (m)
Concrete precast	0.4x0.4	19.0

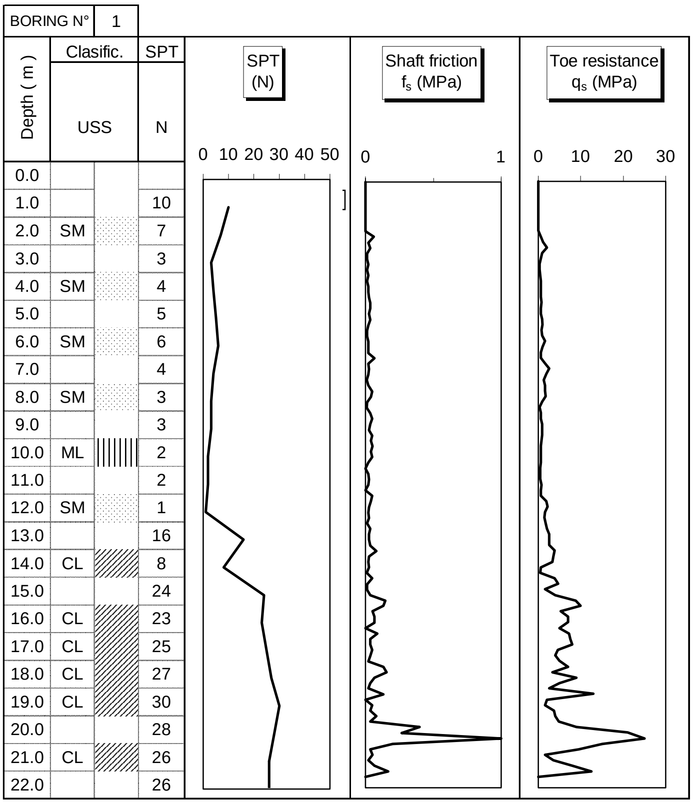


In order to determine the pile length in different areas of the building site, Pile Driving Analysis (PDA) was performed, monitoring Driving Resistances, Enthru Energy, Stresses, etc. The 100% of the pile population was tested with SIT searching for cracked piles, 10% of the foundation (20 piles) was tested dynamically and only 1 ‘slow’ SLT was performed to have a correlation between both methods. The summary of these investigations is presented on Table 4.

Table 4. Test programme.

Test Type	Quantity	Service Load (MN)	Max. Test Load (MN)	Maximum Settlement (mm)
PDA	40	-	-	-
DLT	20	1.2	2.9	4.8
SLT	1	1.2	2.4	3.8

Figure 3. Geotechnical profile.



It is interesting to discuss what happened with this correlation. Due to the unreal short period of time allowed to finish all the driving works, the Engineer decided to perform the Dynamic Load Test immediately after driving- although GEOTECNICA CIENTEC intended to persuade him not to do so because a less total resistance was going to be obtained due to the influence of pore pressure.

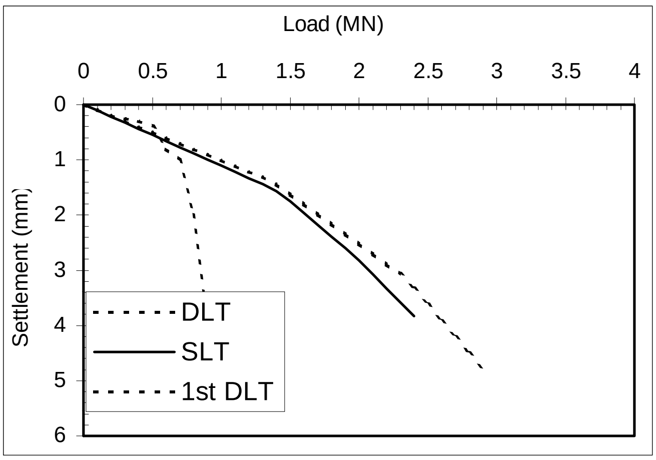
The geotechnical information, described on Figure 3, shows the stratigraphic profile throughout SPT and CPT tests. Because discrepancies were detected during the original borings in different areas of the site, Dutch Cone was used. It was also very useful the Pile Driving Prediction (PDP), performed before the first pile was driven, to select the most suitable diesel hammer.

On Figure 4, the results of the load tests performed on pile N° 135 are plotted, where the first DLT carried out did not fulfilled the expectations- due to what was mentioned above. After the results were available, the Engineer decided to perform the SLT two weeks later, having in mind that the test could not be taken to failure because it was a service pile. Five days after finishing the Static test, the piling rig was used to redrive pile N° 135 to monitor its dynamic behaviour.

As it can be clearly observed, the differences between the first DLT and the SLT as well as among the dynamic ones was caused because it was not taken into account that in cohesive saturated soils, the driving effects on remoulding soil layers and the slow dissipating pore pressure cause a reduction of the bearing capacity.

Conclusions: Dynamic Load Tests are affected by local geotechnical characteristics as well as by soil conditions at the moment of carrying out the measurements. This is the reason why the first DLT did not provide reliable information, because the behaviour of the pile-soil interaction during testing was different than that at the design stage. It is the authors’ opinion that in order to perform a better geotechnical design of piles, more efficient and foundation works less expensive, it must be to carry out CPTs tests during the soil investigation programme. In this way better Signal Matches will be obtained between Upper Travelling Waves, because more exact soil models can be evaluated.

Figure 4. DLT and SLT load-settlement curves.



Bridge

In the Province of Santa Fe, Argentina, due to yearly over floods of the Paraná River- caused mainly by heavy rains during the rainy season, many bridges in the area of the lowlands had to be rebuilt and some others expanded.

In this case, the project consisted in raising the level of the road as well as increasing the length of the bridge from one span 10m long to a deck of two spans 15m each.

The geotechnical design for the foundation was based on the soil strata illustrated on Figure 5, adopting bored piles casted under bentonite mud. The pile details are included on Table 5.

Table 5. Pile characteristics.

Pile Type	Bentonite mud	Diameter (m)	Length (m)
Bored	✓	1.20	21.5

The North, South and Intermediate piers had three piles each, which were tested with SIT, aiming for defects such us cracks, soil inclusions, contaminated concrete and their real lengths. The testing programme carried out is shown on Table 6.

From the interpretation of the Sonic Integrity Tests signals, it was concluded that pile N°4 had an impedance reduction.

After a detailed analysis using the Signal Matching technique with TNOWAVE, it was calculated that the abnormality consisted in a reduction of cross section from 1.20m of nominal diameter to 1.12m extended over a length of 0.5m and at a depth of 14.6m, measured from the pile head. With this result, it was decided to go further on in the investigations, in order to determine the real behaviour of the pile-soil interaction and measure if the foundation element was suitable of transferring loads to the surrounding stratigraphy. A Dynamic and a Static Load Tests were going to be run on pile N°4.

Figure 5. Geotechnical profile.

BORING N° 2

Depth (m)	Clasification USS	SPT N
0.0		
1.0	CL	4
2.0	CH	6
3.0	CH	5
4.0	CL	3
5.0	CL-ML	1
6.0	SP-SM	7
7.0	SM	24
8.0	SP-SM	50
9.0	SP-SM	42
10.0	SP-SM	42
11.0	SP-SM	41
12.0	SP-SM	26
13.0	SP-SM	18
14.0	SP-SM	24
15.0	SP-SM	32
16.0	SP-SM	37
17.0	SC	50
18.0	SP-SM	50
19.0	SP-SM	50
20.0	SP-SM	50
21.0	SP-SM	50
22.0	SP-SM	50
23.0	SP-SM	50
24.0	SP-SM	50

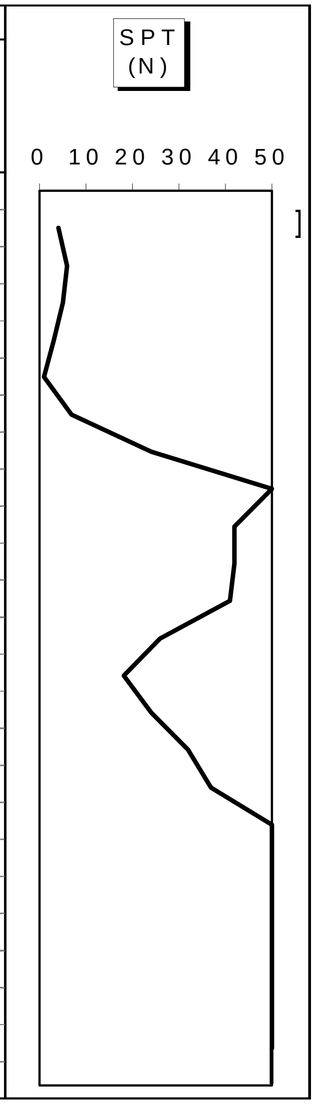


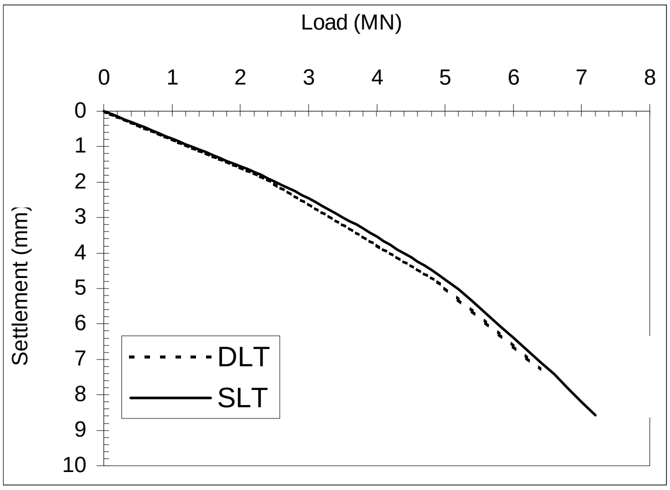
Table 6. Test programme.

Test Type	Quantity	Service Load (MN)	Max. Test Load (MN)	Maximum Settlement (mm)
DLT	1*	4.0	6.5	7.3
SLT	1	4.0	7.2	8.6

Note *: Originally 1 SLT and 1 DLT were projected, but as one pile was damaged it was agreed to perform a second DLT.

Due to the local geological conditions, mainly sandy soil, a ‘quick’ Static Load Test was going to be performed because the creep effect was not critical for the bridge behaviour. The results are plotted on Figure 6 jointly with its dynamic counterpart.

Figure 6. DLT and SLT load-settlement curves.



Conclusions: At it is clearly presented, the Dynamic Load Test can have an accurate static correlation, inclusive for high loads- 7MN as in this case.

As in the previous cases, the building and the industrial facility projects, it is an irrevocable condition - in order to obtain a good match or correlation between dynamic and static measurements of a same phenomenon pile-soil interaction - to have an exhaustive geotechnical investigation, knowledge of the parameters of the materials used for the construction on the foundation and the pile shape. Although some skepticism, that still over flies on some Engineer's minds, Dynamic Load Testing is reliable if the above conditions are fulfilled, inclusive for high loads in cast in-situ piles.

GENERAL CONCLUSIONS.

In the above case histories, where piles varied in dimensions and construction methods- from driven precast concrete to bored piles under slurry, throughout Franki type; installed in clay, lime and sand affecting the pile-soil interaction in different ways under small to big loads, they all have a common denominator.
That common denominator is, leaving aside the fact that all tests were properly performed, recorded and post-processed, the quality of the basic information. In other words, the geotechnical information, dimensions and pile shape, mechanical properties of materials used and the installation procedure.

For both types of test, Dynamic (DLT) and Static (SLT), that information is vital. Notable contradiction, because it is required for both designing the test and interpretation of results. It is useless to obtain huge amount of data, in white paper in case of a SLT or a computer file for a DLT, in order to be plotted as the 'Load-Settlement Curve' and handed in to the Client as a great achievement certifying that 'the pile will stand the load' without the geotechnical-structural diagnosis. In other words, the interpretation!
If not, effort, time and money would have been wrongly spent…three not refundable goods in any aspect of life.

But making an abstraction and travelling to the Contractors' Paradise, where no testing is required and QA has not been invented- not even as a concept. Nevertheless, would not be necessary to know the geotechnical investigation, material properties and selected pile in order to construct the project?
In almost all the above case histories, a good correlation between Dynamic and Static Load Tests was obtained, satisfying the expectations for homologation of both methods. It is a fact the acceptance for DLT from the local market and its growing reliability, due that it provides similar results than the Static Test with almost no delays on site and reduced budget.

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