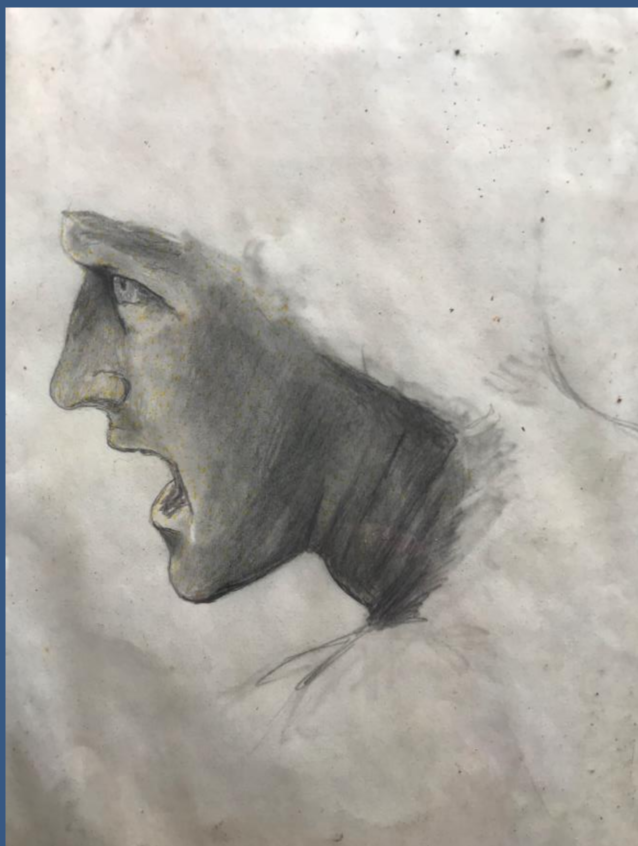
HISTORY OF THE STATNAMIC LOAD TEST.

30MN STATNAMIC TEST BY FUGRO JAPAN FOR JAPANESE HIGHWAY AUTHORITY

October 2021

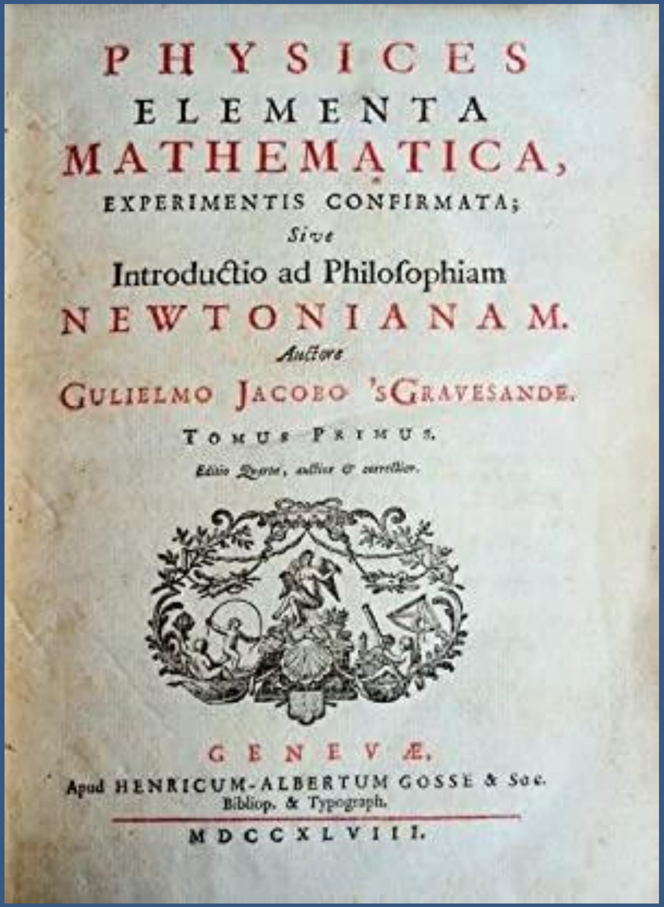
TRAINED ARTIST SELF TAUGHT ENGINEER



The Spectator, Tuesday, April 2, 1974

How a beam launcher is used to build a bridge is explained by Patrick Bermingham.

WILLIAM GRAVESANDE

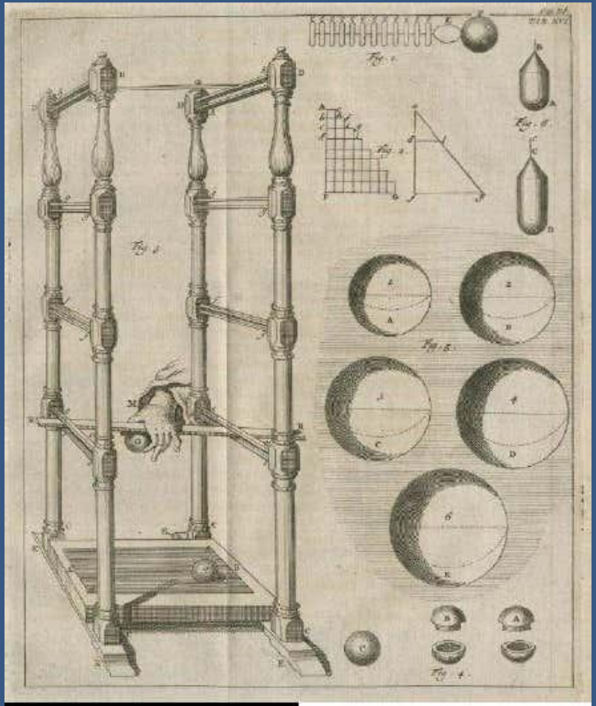


PHYSICES
ELEMENTA
MATHEMATICA,
EXPERIMENTIS CONFIRMATA;
Sive
Introductio ad Philosophiam
NEWTONIANAM.
Auctore
GULIELMO JACOBO 'S GRAVESANDE.
TOMUS PRIMUS.
Editio Quarta, auctior & correctior.

GENEVÆ,
Apud HENRICUM-ALBERTUM GOSSE & Soc.
Bibliop. & Typograph.
MDCCXLVIII.

THE VIS VIVA CONTROVERSY

E = M X V OR E = M X V²



Quâ Sphæræ Segmenta, & Coni, ex datis Diametris, conferuntur, diviso Hæmisphærio in mille partes, & hujus Diametro in Centum. 867.

Diam.	Segment. Profund.	Segm.	Coni.	Diam.	Segment. Profund.	Segm.	Coni.
35.			23.	68.	13.	97.	172.
36.			25.	69.	14.	104.	179.
37.			27.	70.	14.	111.	187.
38.			30.	71.	15.	118.	195.
39.			32.	72.	15.	126.	203.
40.			35.	73.	16.	134.	212.
41.			38.	74.	16.	143.	221.
42.			40.	75.	17.	152.	230.
43.			43.	76.	17.	162.	239.
44.			46.	77.	18.	173.	249.
45.			49.	78.	19.	184.	259.
46.			52.	79.	19.	196.	269.
47.			56.	80.	20.	208.	279.
48.			60.	81.	21.	221.	290.
49.			64.	82.	21.	235.	301.
50.	7.	26.	68.	83.	22.	250.	312.
51.	7.	28.	72.	84.	23.	266.	323.
52.	7.	30.	77.	85.	24.	283.	335.
53.	8.	33.	81.	86.	24.	301.	347.
54.	8.	36.	86.	87.	25.	320.	359.
55.	8.	39.	91.	88.	26.	341.	372.
56.	9.	42.	96.	89.	27.	363.	385.
57.	9.	45.	101.	90.	28.	387.	398.
58.	9.	48.	106.	91.	29.	414.	411.
59.	10.	52.	112.	92.	30.	442.	425.
60.	10.	56.	118.	93.	32.	473.	439.
61.	10.	60.	124.	94.	33.	508.	453.
62.	11.	64.	130.	95.	34.	547.	468.
63.	11.	69.	136.	96.			483.
64.	12.	74.	143.	97.			498.
65.	12.	80.	150.	98.			514.
65.	12.	85.	157.	99.			530.
67.	13.	91.	164.	100.	50.	1000.	546.

Vis viva a historic term used for the first recorded description of what we now call kinetic energy

DROP WEIGHT TESTS ON SOFT CLAY

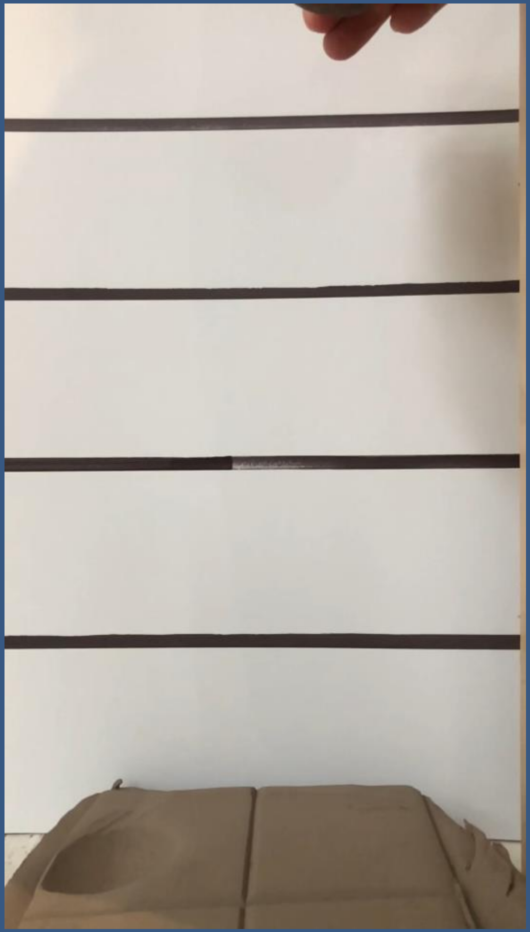
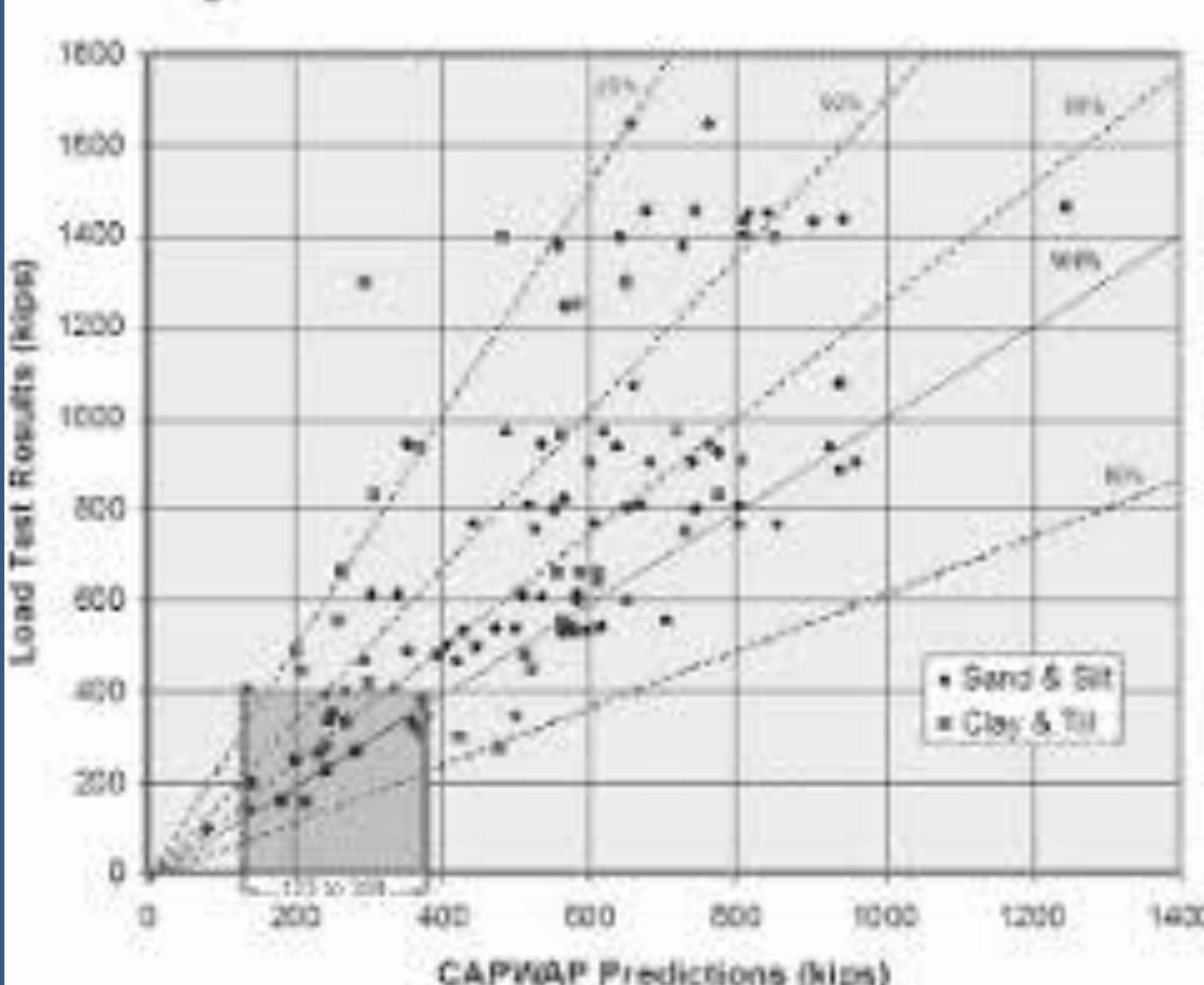
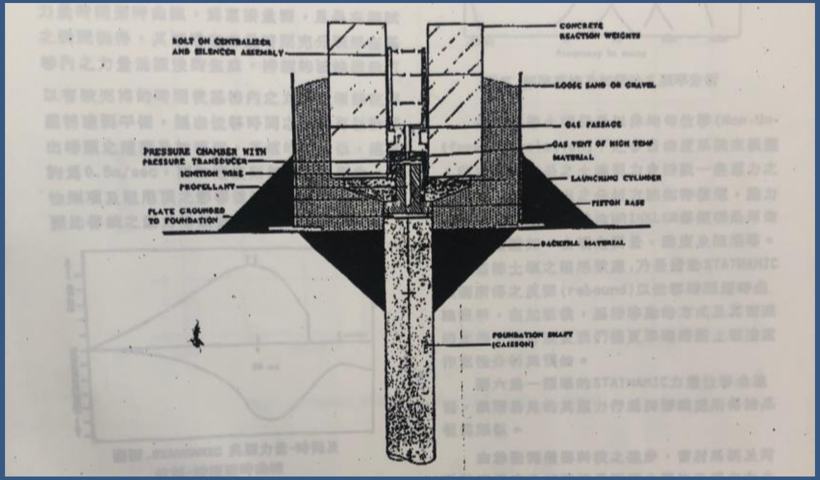


Figure 1 - *Load Test Versus CAPWAP Predictions*

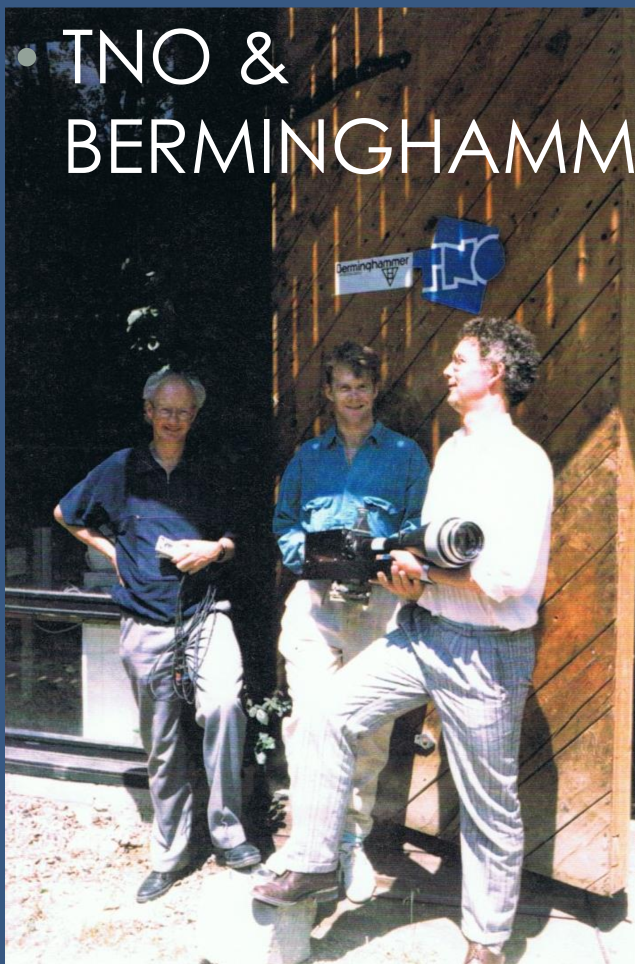


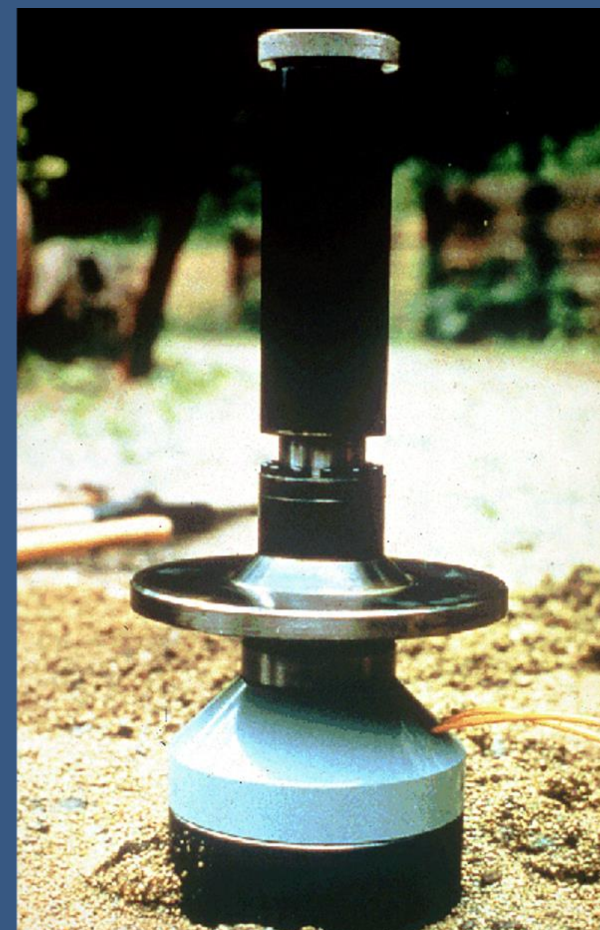
- In 1980's the foundation industry was looking for faster and more economical means of load testing drilled shafts and high capacity foundations (ADSC)
- Bengt Fellenius asked me to design a drop weight system that could apply a 600 tonne load & fit in a van.
- The idea was born in his back yard in Ottawa.
- I went to a seminar on dynamic testing held at the university of Boulder Colorado in the mid 1980s.
- After the conference, I proposed the idea of launching a weight upward off the top of a pile to George Goble, Ph.D and Garland Likins P.E.: "***Ridiculous! It would be impossible to transfer any energy into the pile in that way".***
- Then I knew that it would work



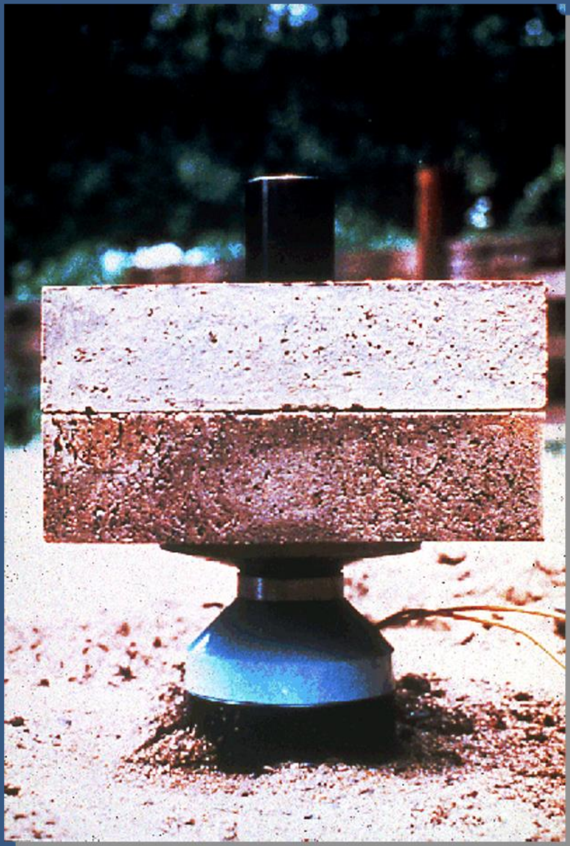
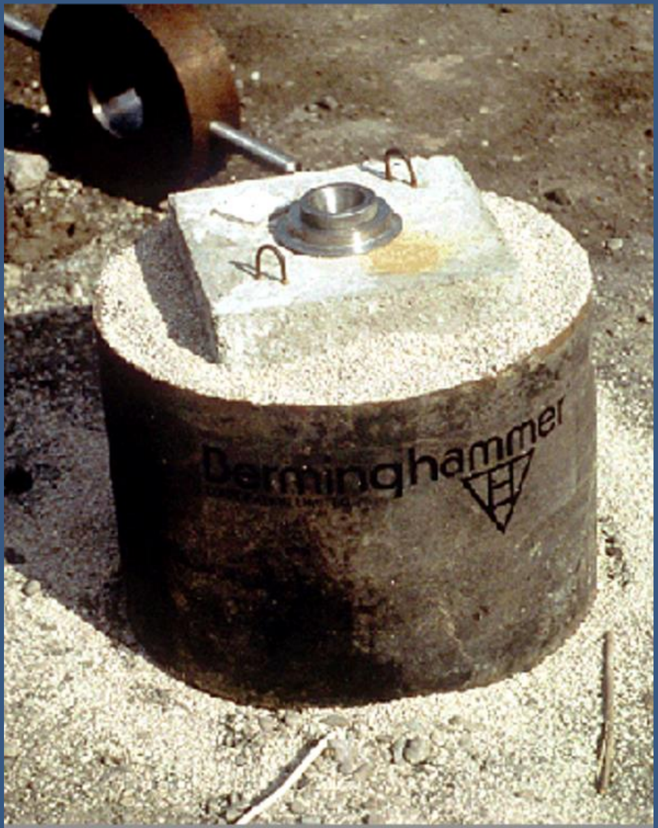
A PARTNERSHIP AMONG AN ARTIST, A SCIENTIST AND AN ELECTRICAL ENGINEER WAS FORMED IN 1988

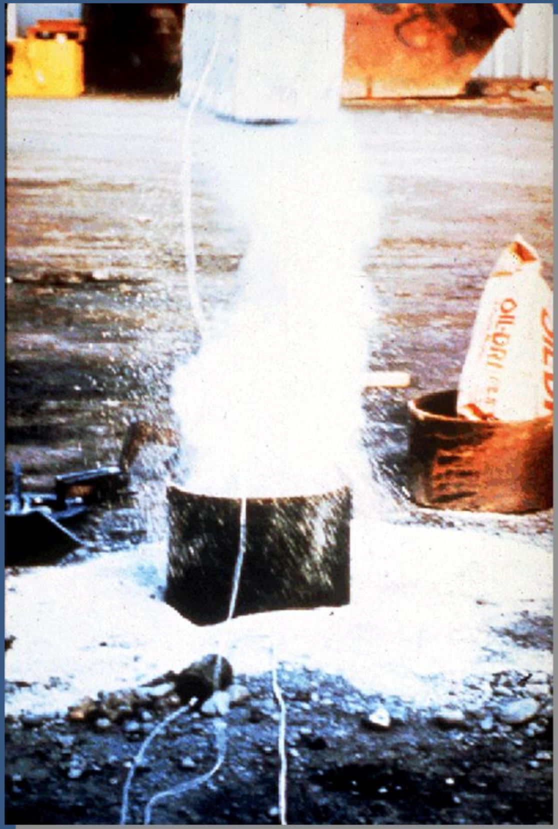
- TNO & BERMINGHAMMER



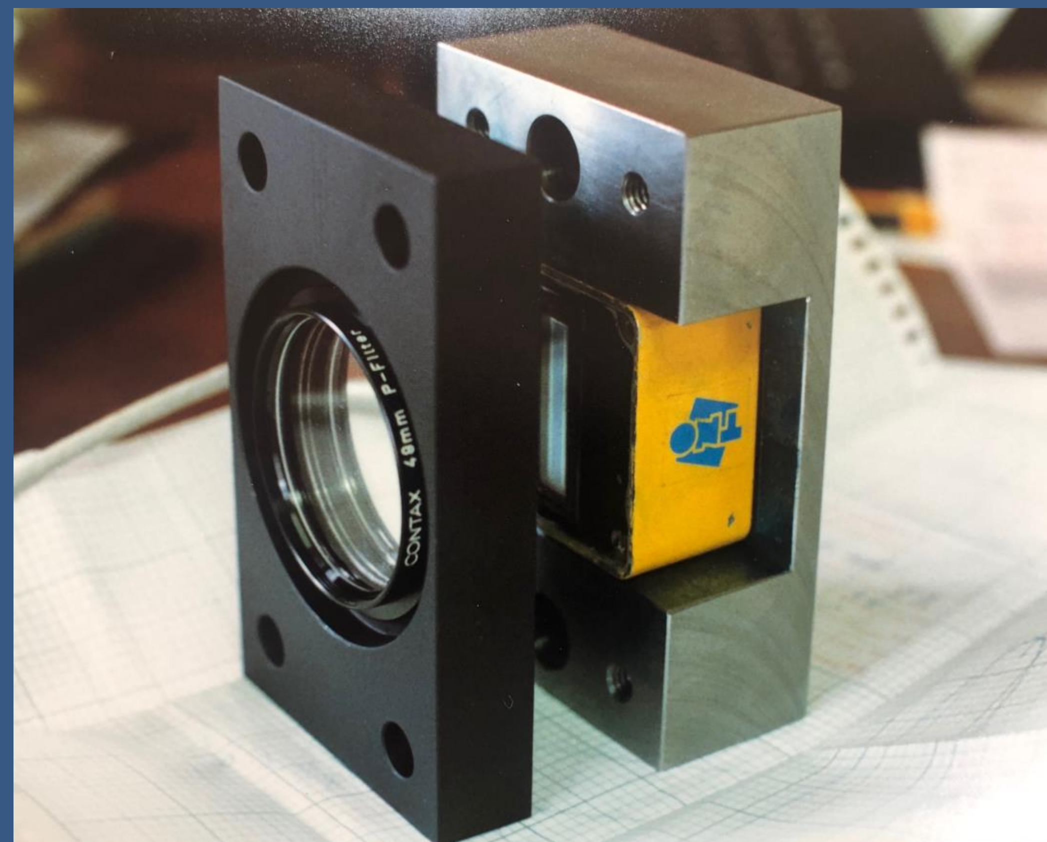


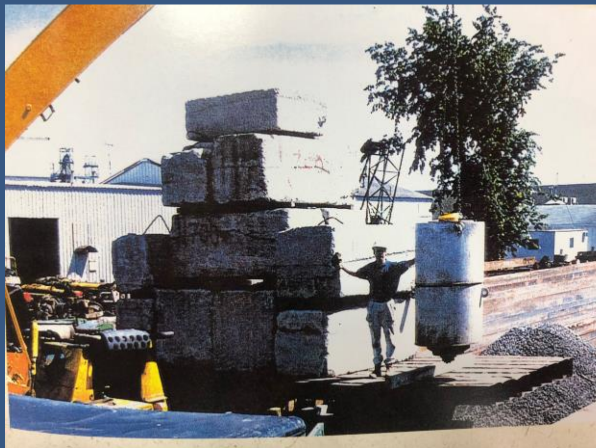
FIRST STATNAMIC DEVICE 0.1 MN

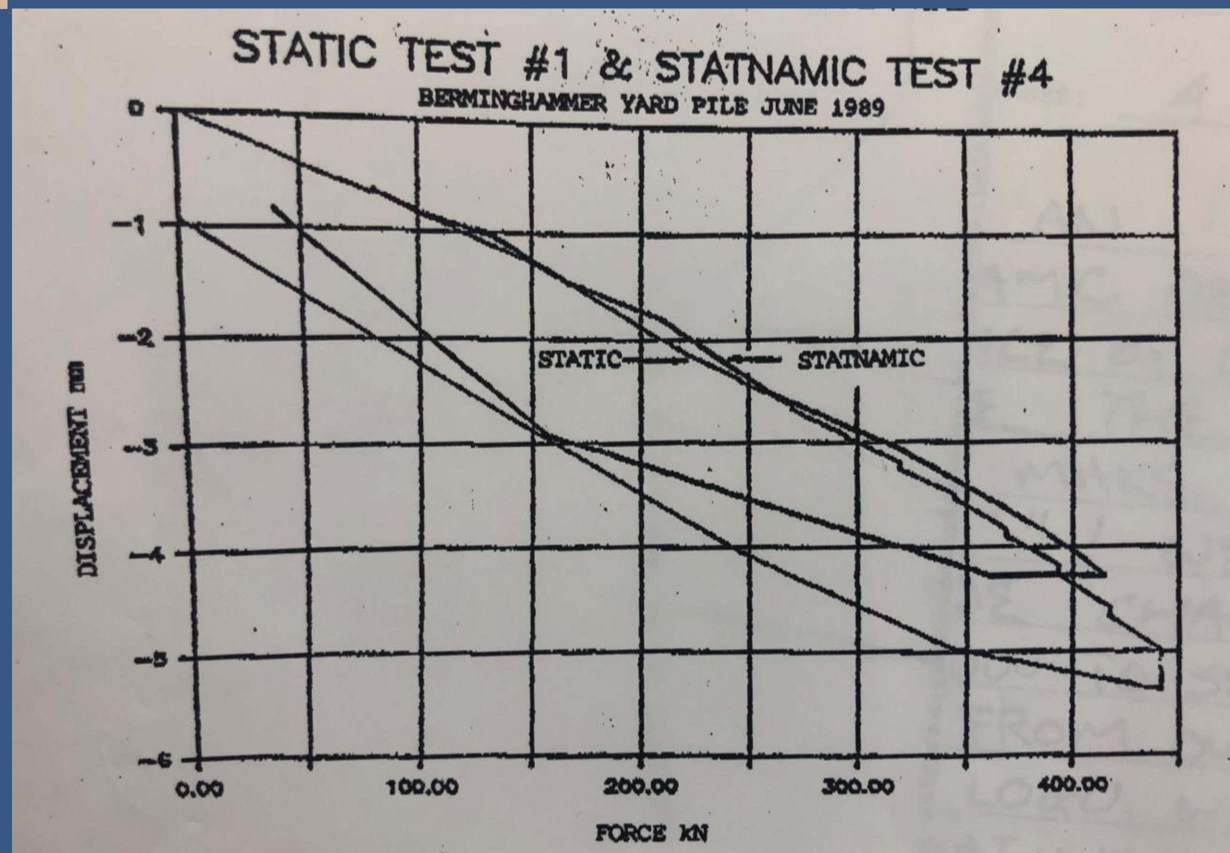


Helium neon red laser and optical transducer





The first Statnamic® and Static test comparison in 1989 Hamilton Ontario



ASHBRIDGES BAY LOAD TESTING CIRCA 1990 WITH A 0.5 MN DEVICE

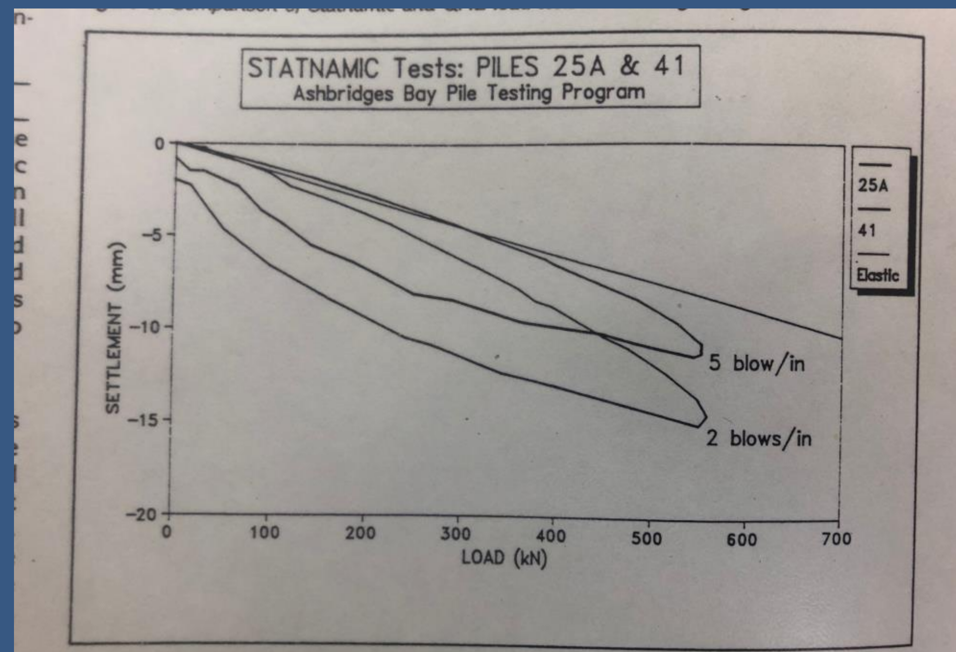
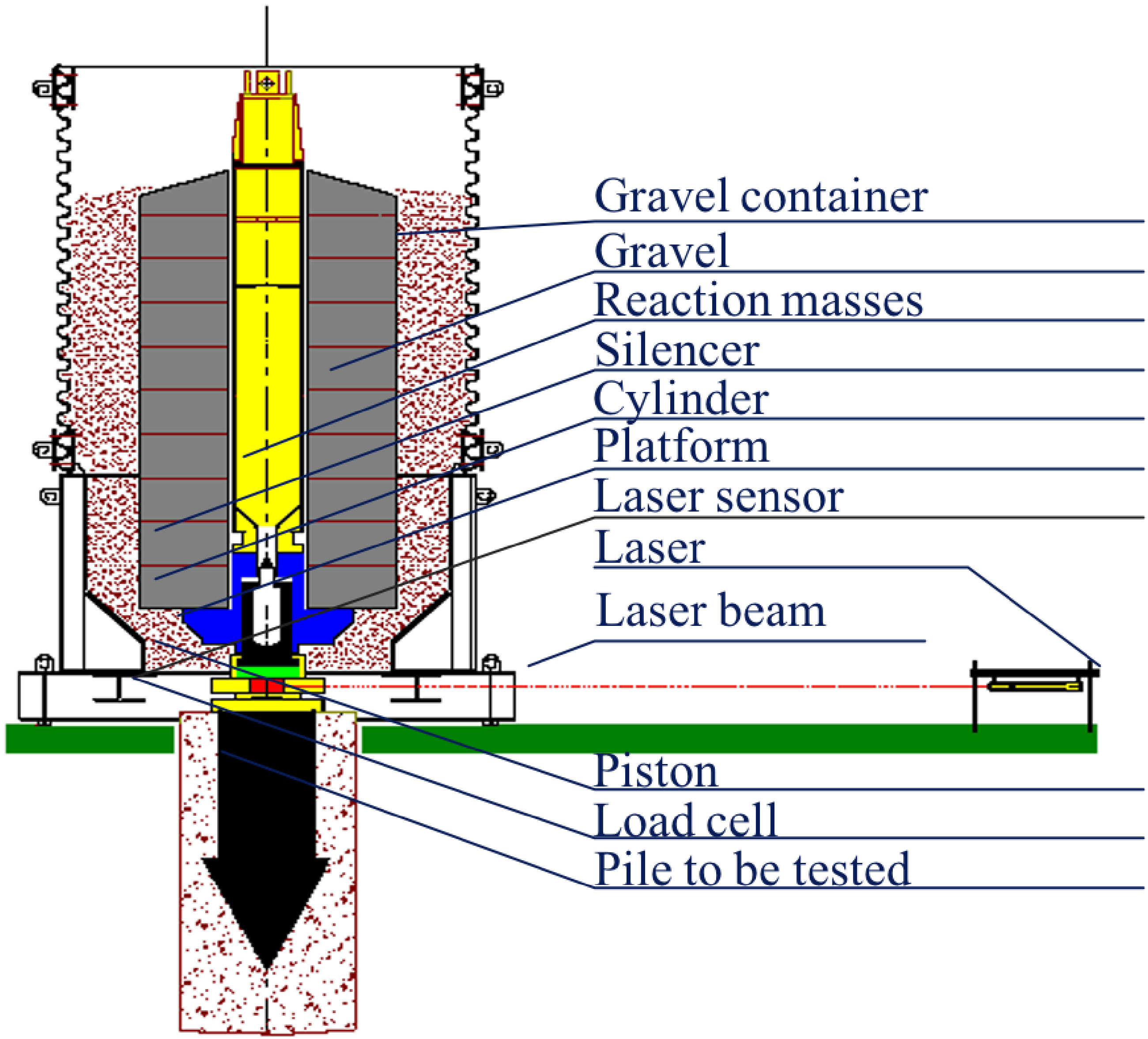
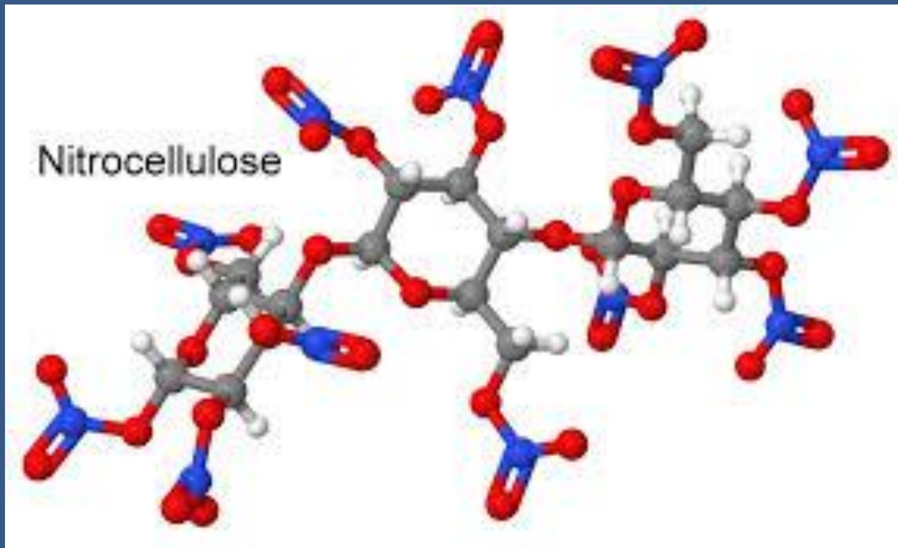
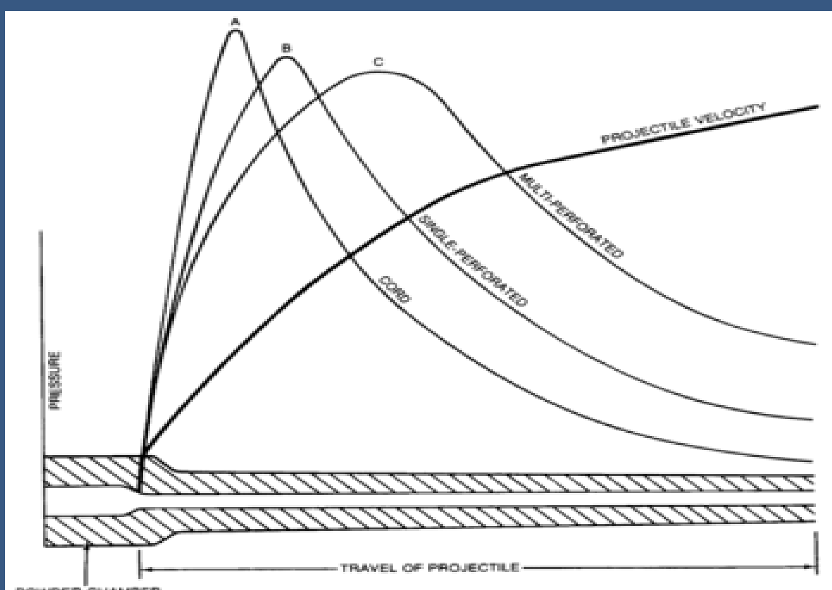


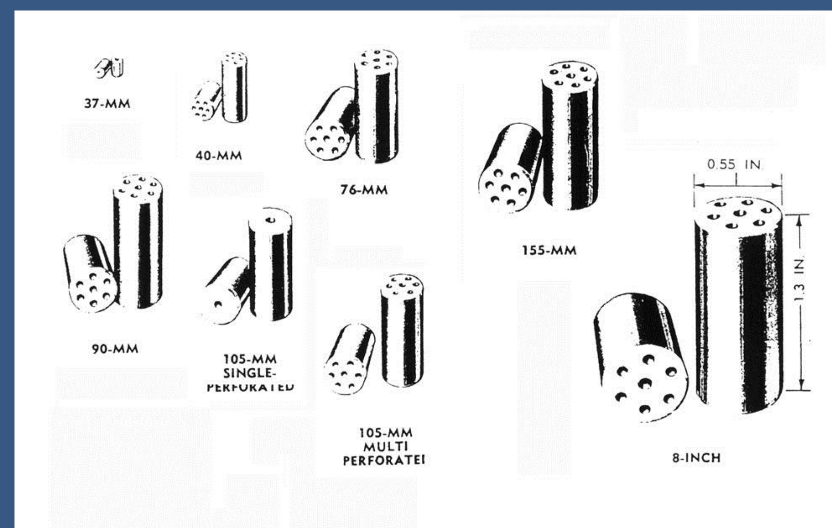
Figure 2: Comparison of Statnamic load tests on piles driven to 2 and 5 blows per inch.

design load indicate that the dif- ASTM Quick Maintained Load


Gravel container
Gravel
Reaction masses
Silencer
Cylinder
Platform
Laser sensor
Laser
Laser beam
Piston
Load cell
Pile to be tested

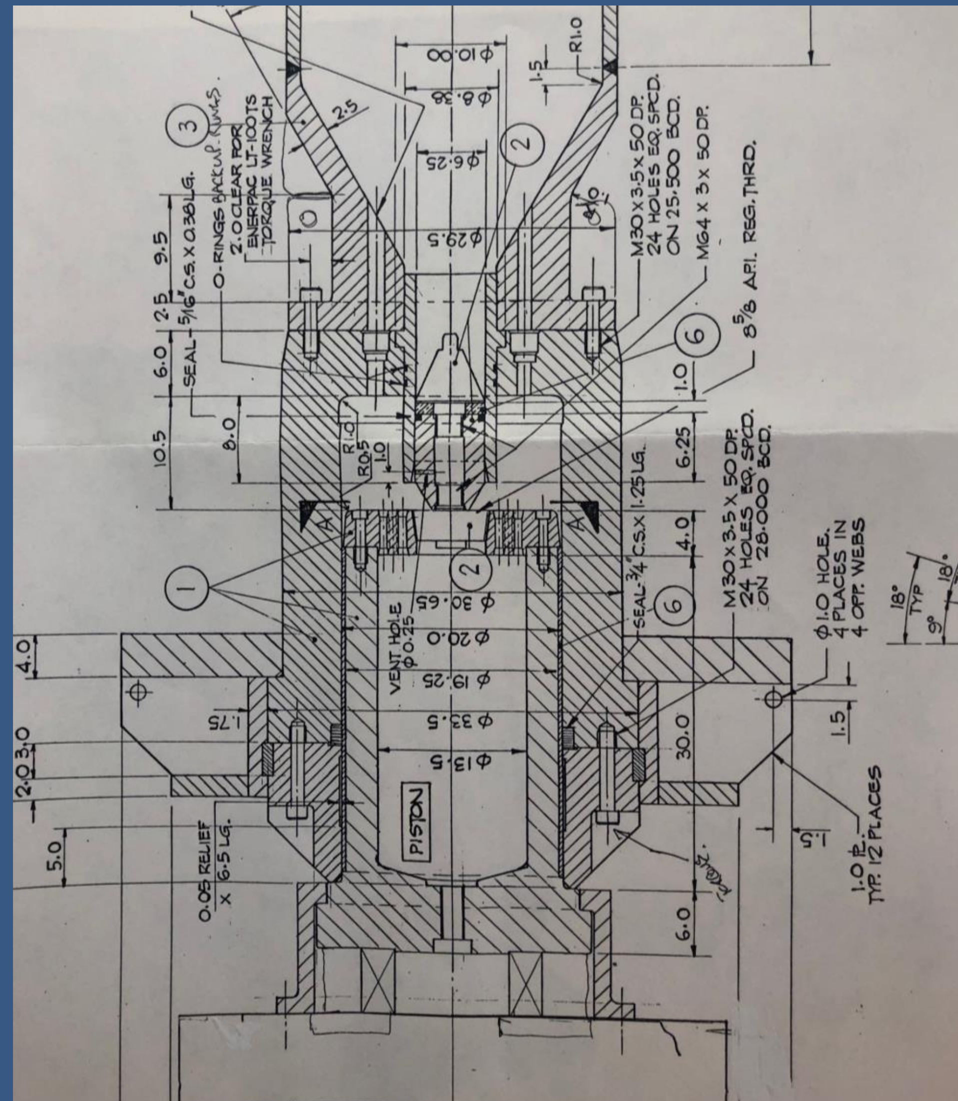

Nitrocellulose


A
B
C
PROJECTILE VELOCITY
MULTI-PERFORATED
SINGLE-PERFORATED
CORD
PRESSURE
TRAVEL OF PROJECTILE
POWDER CHAMBER

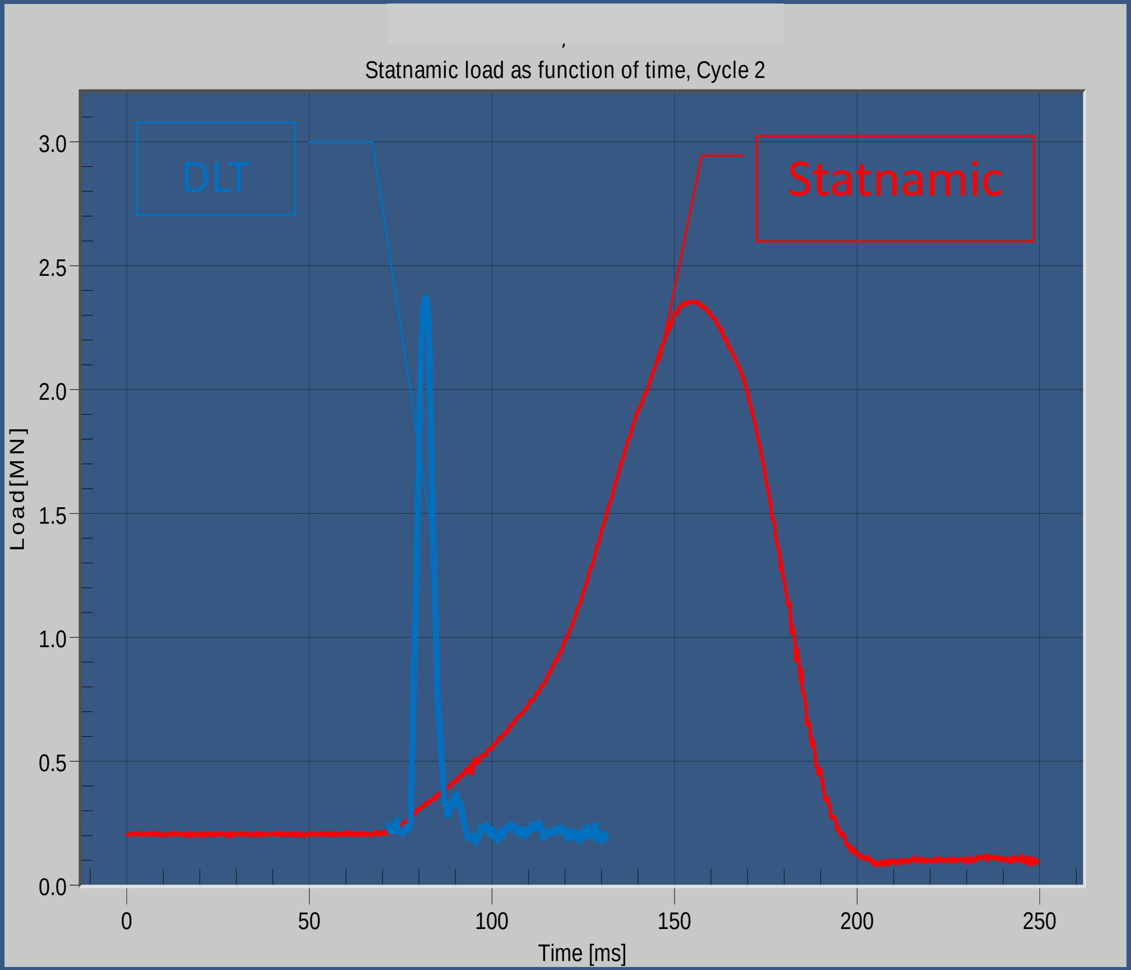

37-MM
40-MM
76-MM
155-MM
90-MM
105-MM SINGLE-PERFORATED
105-MM MULTI PERFORATE
0.55 IN.
1.3 IN.
8-INCH

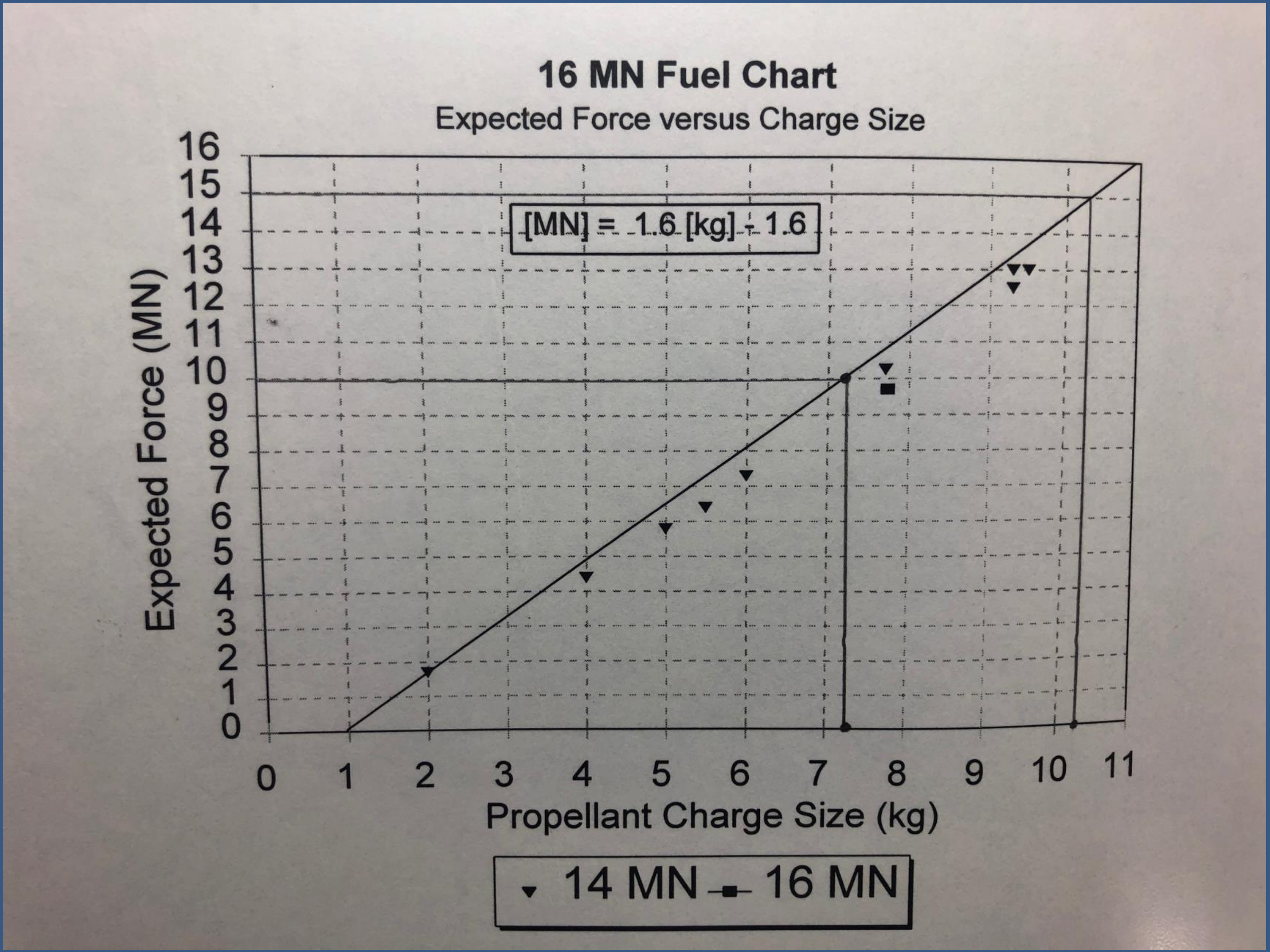
A HIGH PRESSURE JACK

- Operating pressure of 1000 atmospheres
- Low loading density
- Controlled ignition
- A power stroke of between 100mm and 150mm



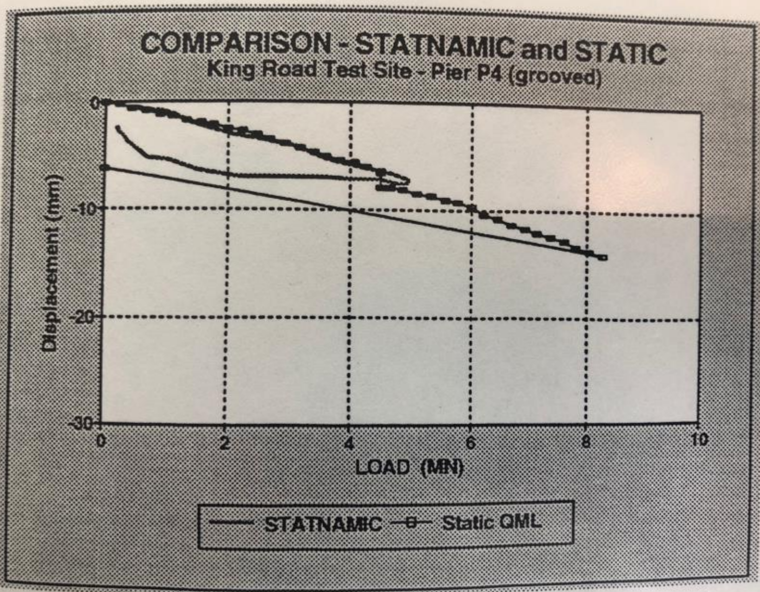
Load duration STN and DLT




16 MN Fuel Chart
Expected Force versus Charge Size
[MN] = 1.6 [kg] - 1.6
Expected Force (MN)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0 1 2 3 4 5 6 7 8 9 10 11
Propellant Charge Size (kg)
14 MN
16 MN

Statnamic

Long duration load, quasi-static pile and soil behavior



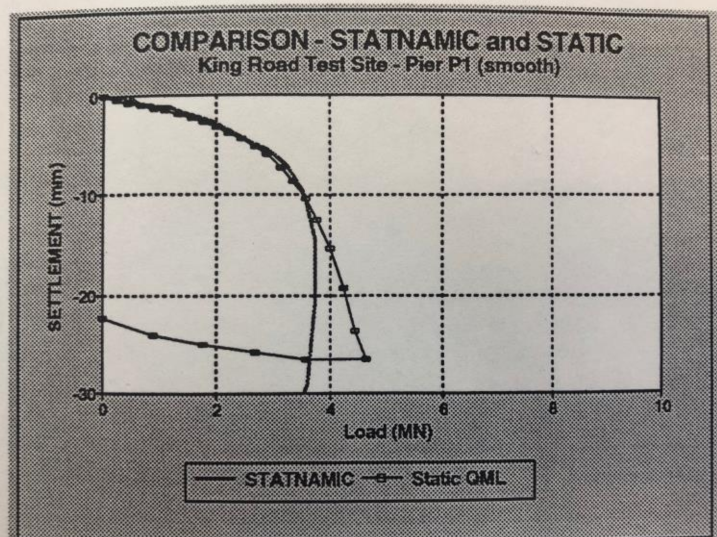


Figure 2.3

CON
The f
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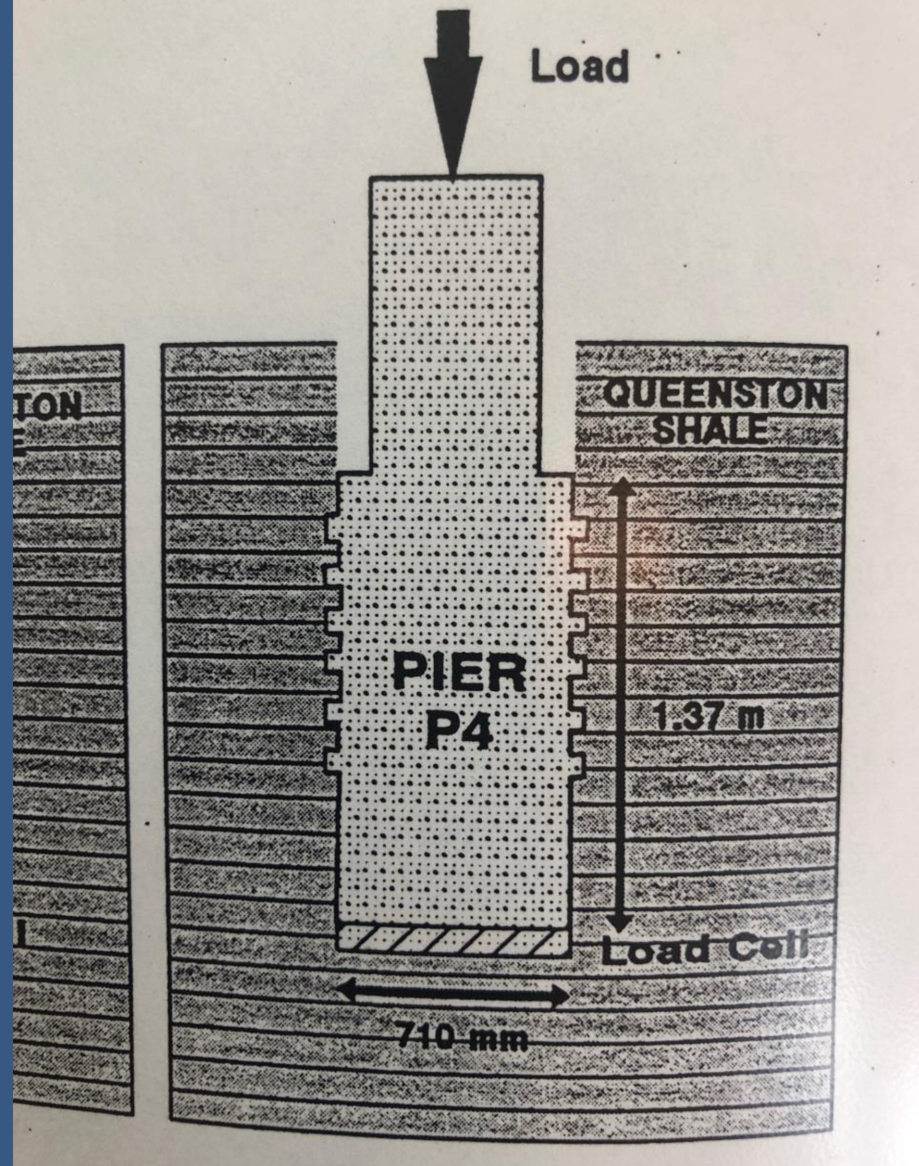
test.

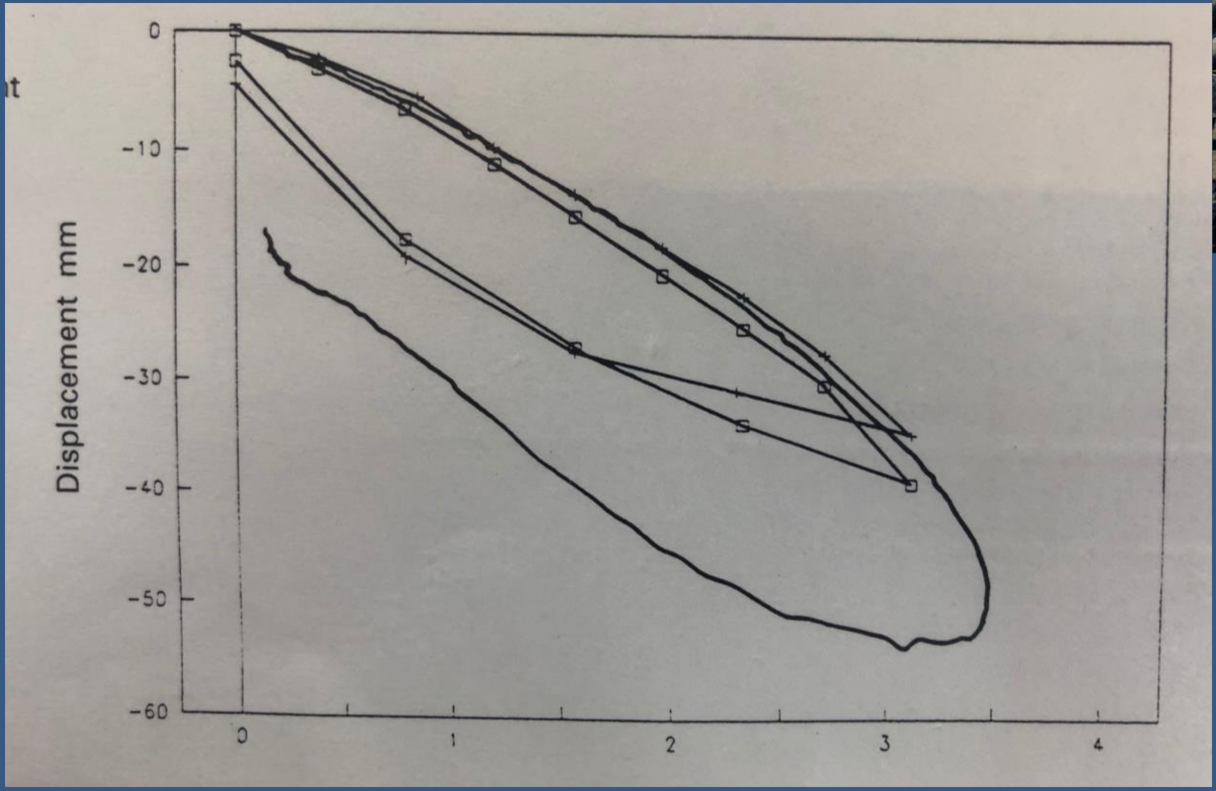
For th
load-
socke
loadi
displa
the co

The S
a sig
static



Hunt club road In Ottawa Canada

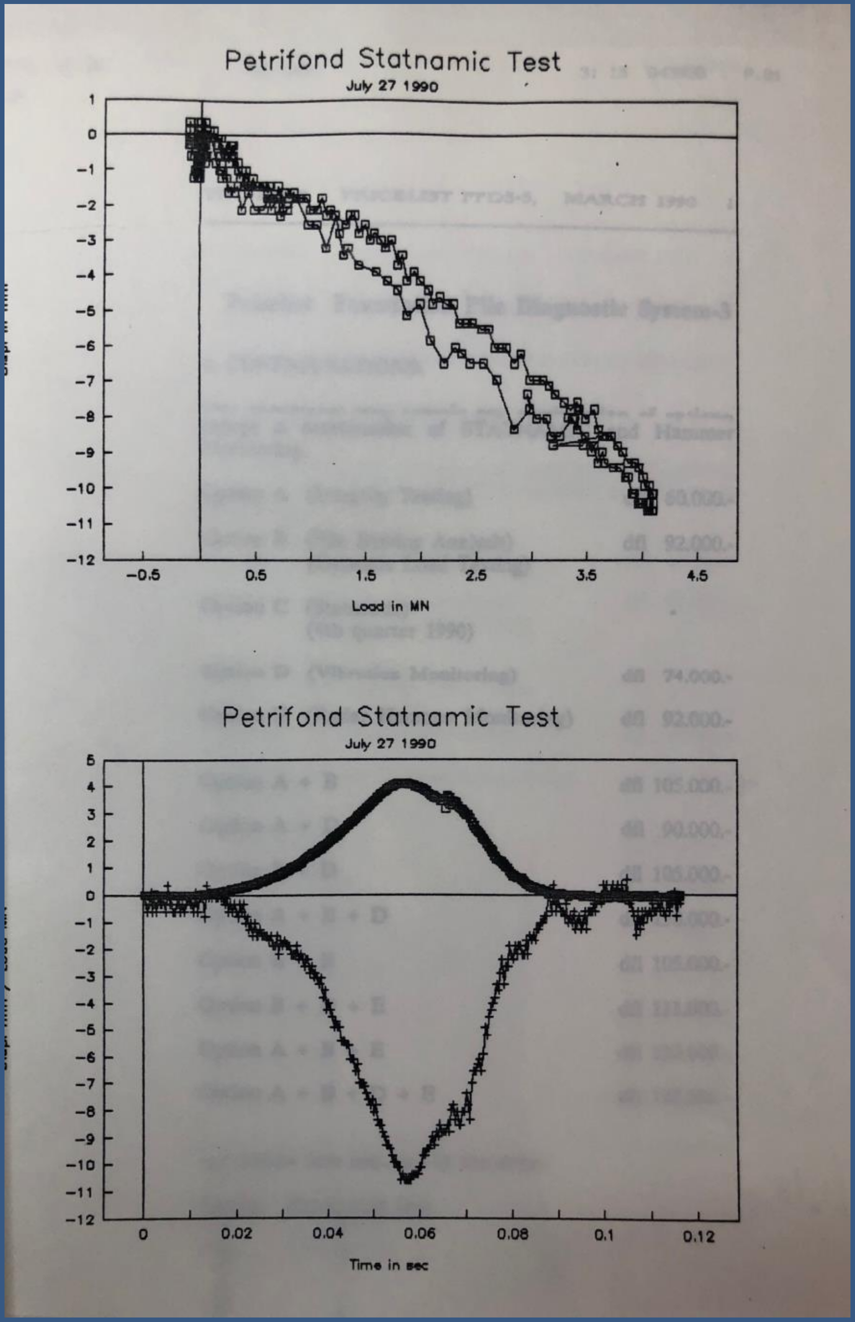
Statnamic test compared to two static tests performed with soil anchors. The test took one day vs two weeks for the static tests



TEST ON 1:3 SPIN FIN PILE

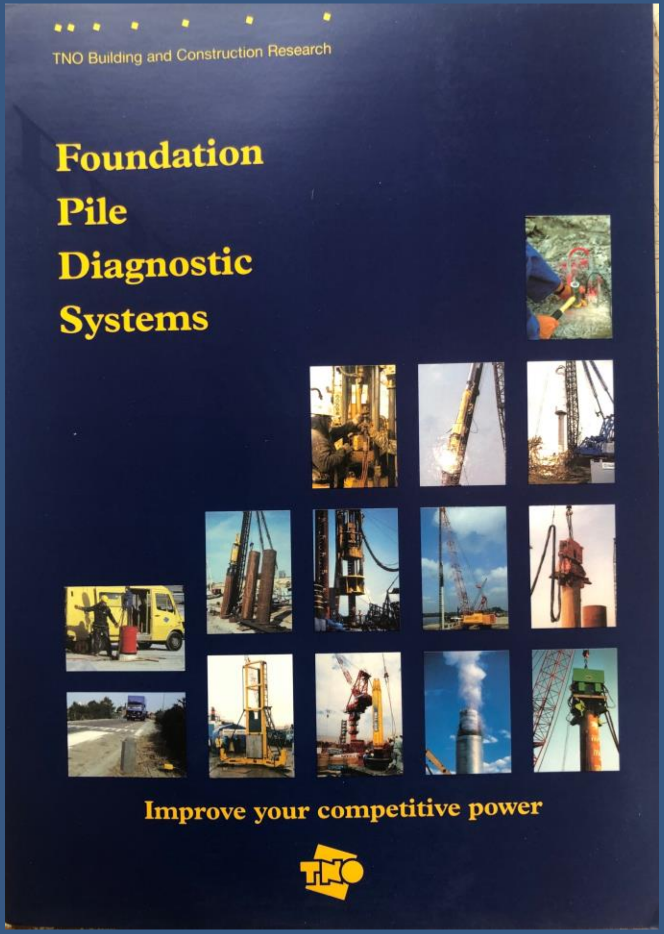
DIRECT MEASUREMENT OF LOAD , DISPLACEMENT.

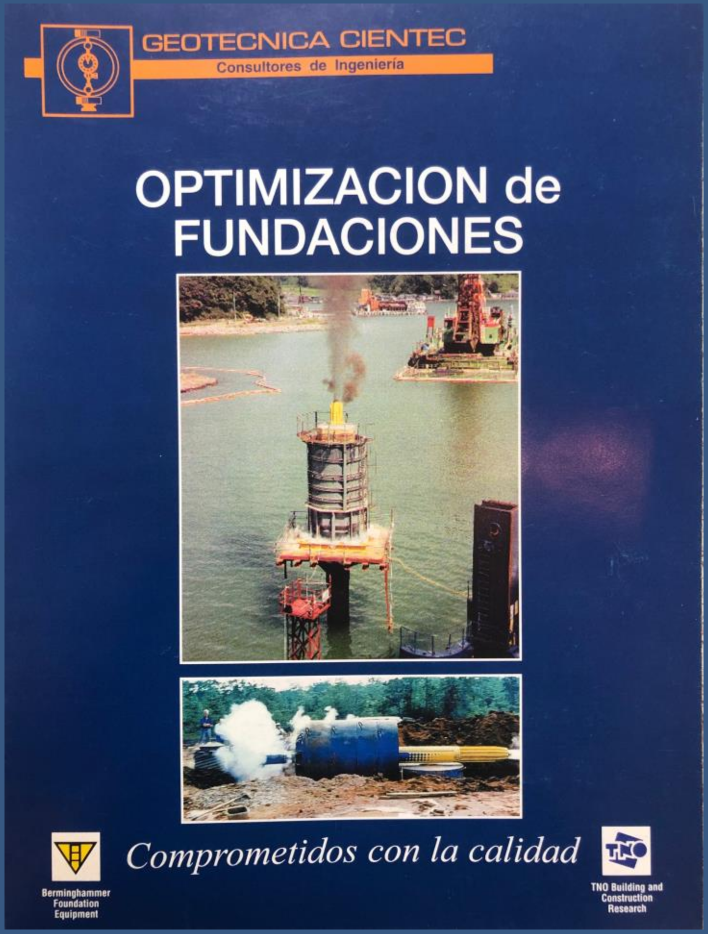
- Digital data acquisition providing 2000 readings of load and displacement during a tenth of a second.
- Simplicity and repeatability over theory and estimations.

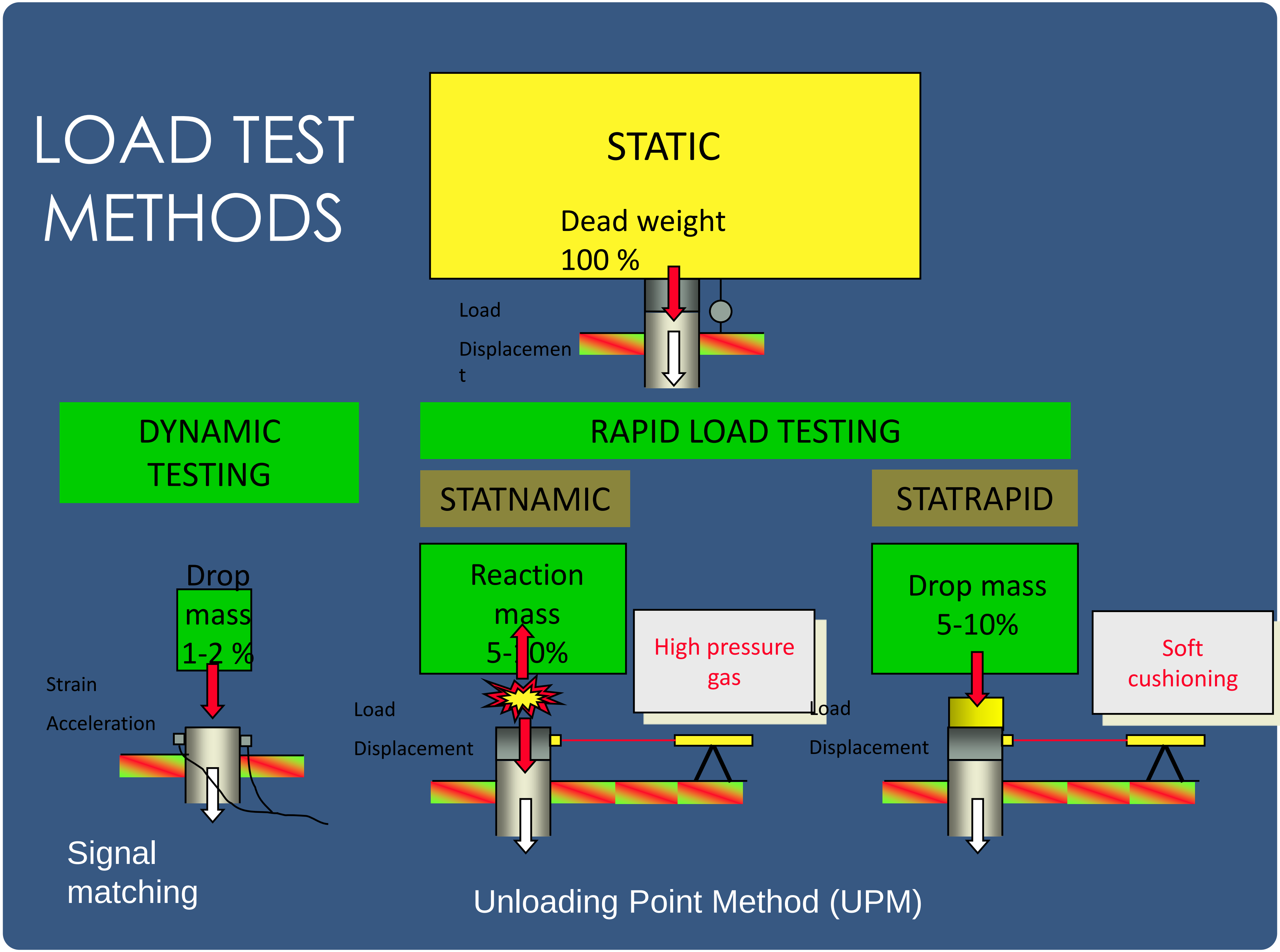


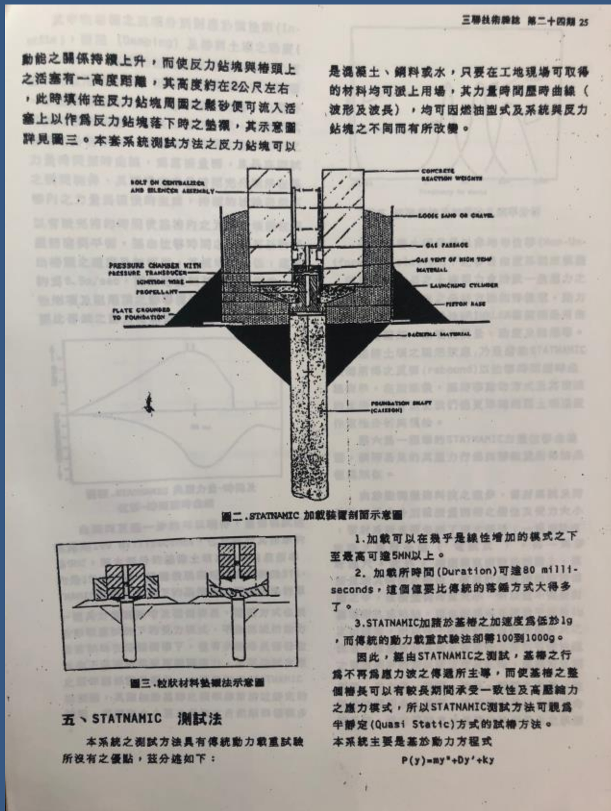

1600 TON

PART OF THE TNO FAMILY






LOAD TEST METHODS
STATIC
Dead weight
100 %
Load
Displacement
DYNAMIC TESTING
RAPID LOAD TESTING
STATNAMIC
STATRAPID
Drop mass 1-2 %
Strain
Acceleration
Reaction mass 5-10%
High pressure gas
Load
Displacement
Drop mass 5-10%
Soft cushioning
Load
Displacement
Signal matching
Unloading Point Method (UPM)



動能之關係持續上升，而使反力鉆塊與樁頭上之活塞有一高度距離，其高度約在2公尺左右，此時填佈在反力鉆塊周圍之鬆砂便可流入活塞上以作爲反力鉆塊落下時之墊襯，其示意圖詳見圖三。本套系統測試方法之反力鉆塊可以是混凝土、鋼料或水，只要在工地現場可取得的材料均可派上用場，其力量時間歷時曲線（波形及波長），均可因燃油型式及系統與反力鉆塊之不同而有所改變。

圖二.STATNAMIC 加載裝置剖面示意圖

圖三.粒狀材料墊襯法示意圖

五、STATNAMIC 測試法

本系統之測試方法具有傳統動力載重試驗所沒有之優點，茲分述如下：

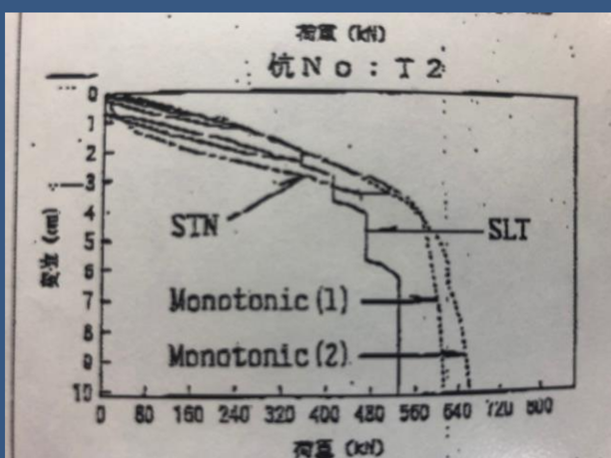
1.加載可以在幾乎是線性增加的模式之下至最高可達5MN以上。

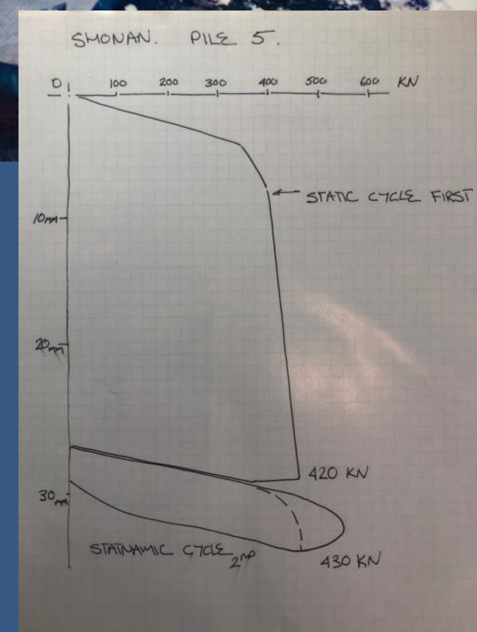
2. 加載所時間(Duration)可達80 milli-seconds，這個值要比傳統的落錘方式大得多了。

3.STATNAMIC加諸於基樁之加速度爲低於1g，而傳統的動力載重試驗法卻需100到1000g。

因此，經由STATNAMIC之測試，基樁之行爲不再爲應力波之傳遞所主導，而使基樁之整個樁長可以有較長期間承受一致性及高壓縮力之應力模式，所以STATNAMIC測試方法可視爲半靜定(Quasi Static)方式的試樁方法。本系統主要是基於動力方程式

$$P(y)=my''+Dy'+ky$$





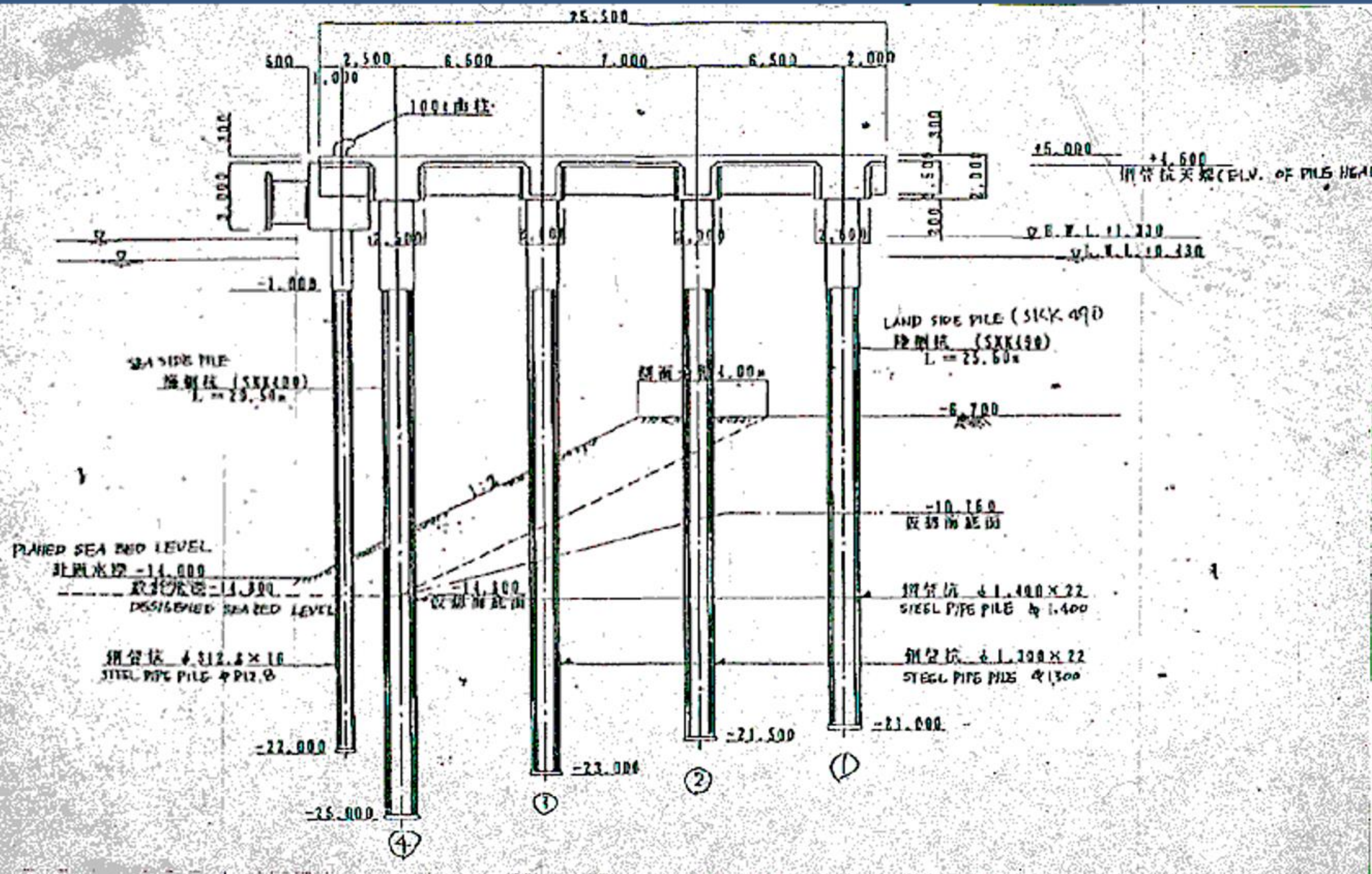
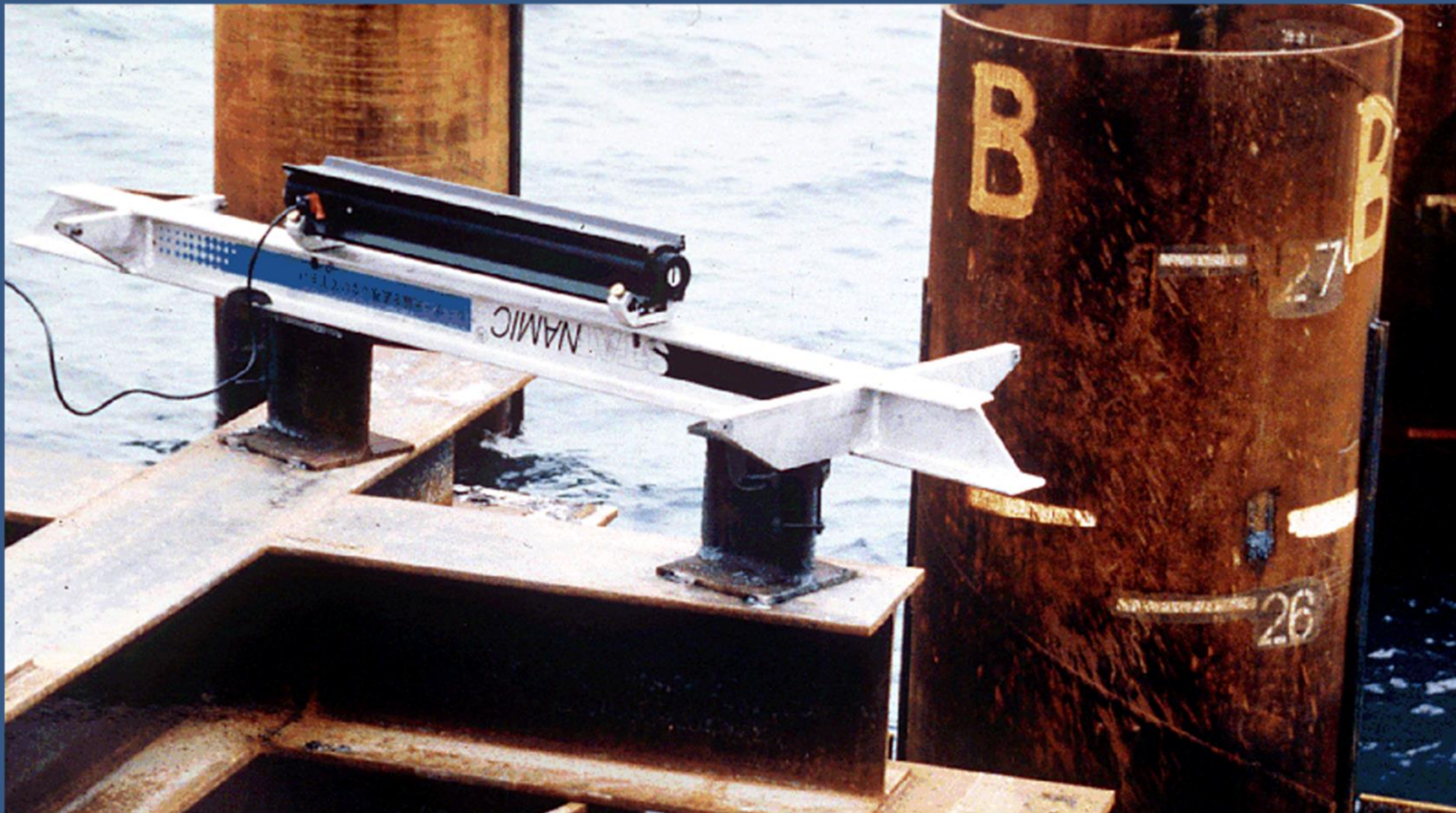


図-1 桟橋構造図(一般部:断面図)
DRW-1 SECTION

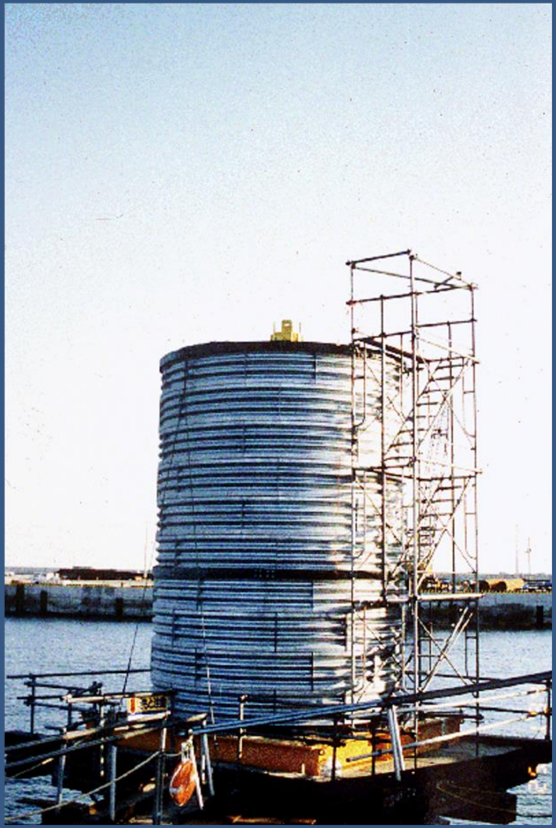
PISTON AND CALIBRATED LOAD CELL

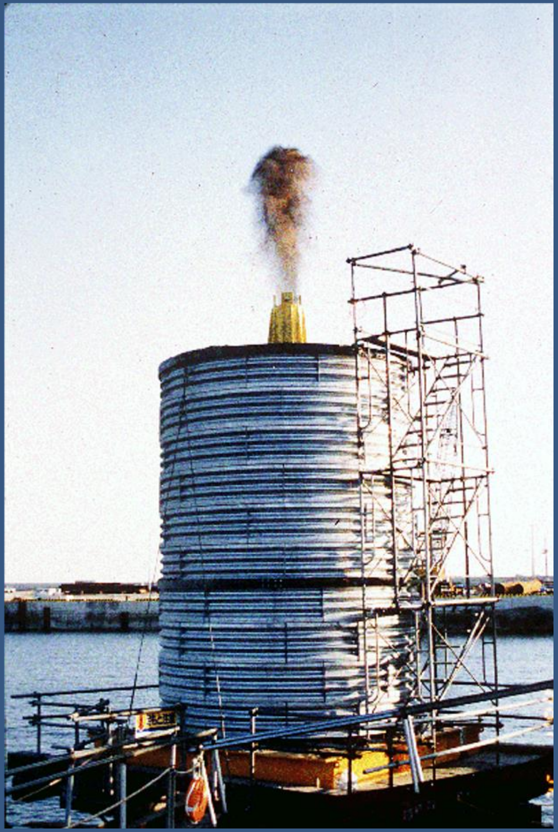

NAMIC
B
B
27
26

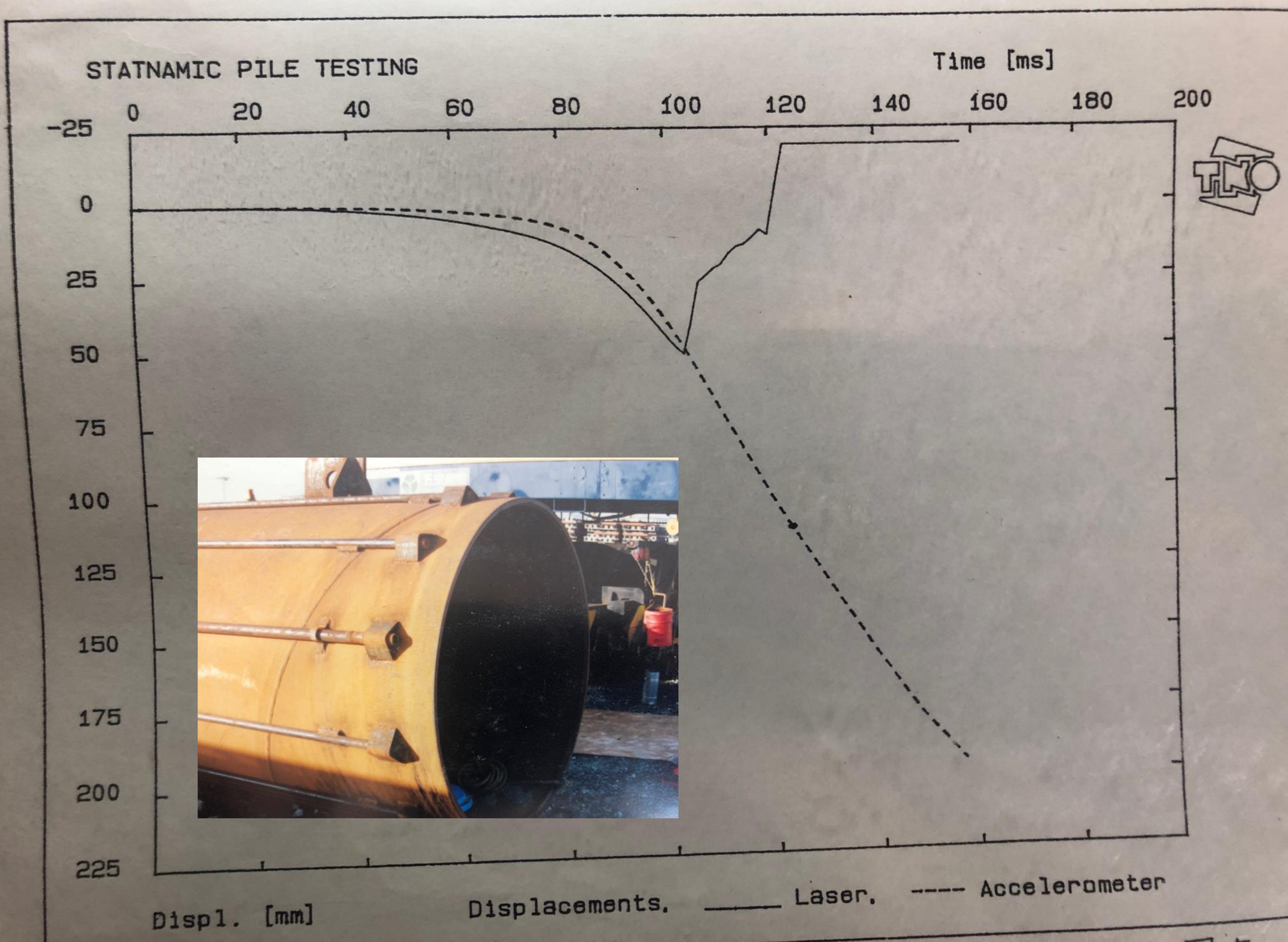

STATNAMIC


VAMIC

FIRST LOAD TEST






STATNAMIC PILE TESTING
Time [ms]
0 20 40 60 80 100 120 140 160 180 200
-25 0 25 50 75 100 125 150 175 200 225
Displ. [mm]
Displacements. ——— Laser. ---- Accelerometer

STATNAMIC WAS TWO THINGS AT THE SAME TIME.

- A powerful means of generating a test load.
- An accurate way of directly measuring the load, displacement and acceleration of the pile.
- Soon to become a standardized test method-- RLT.

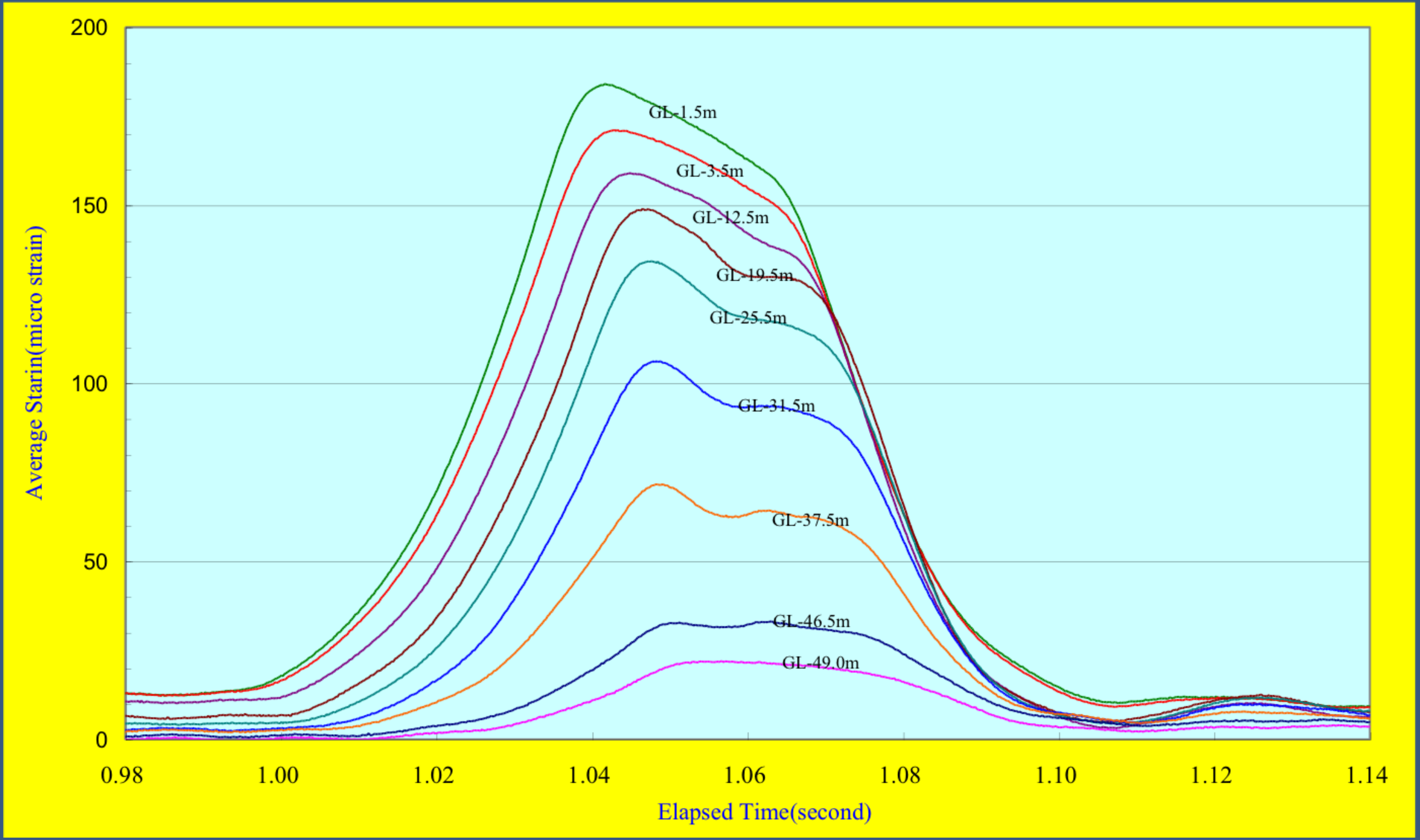
JAPANESE STUDY GROUP

Extensive testing program and acceptance by the Japanese geotechnical society led to the writing of a standard specification for rapid load testing

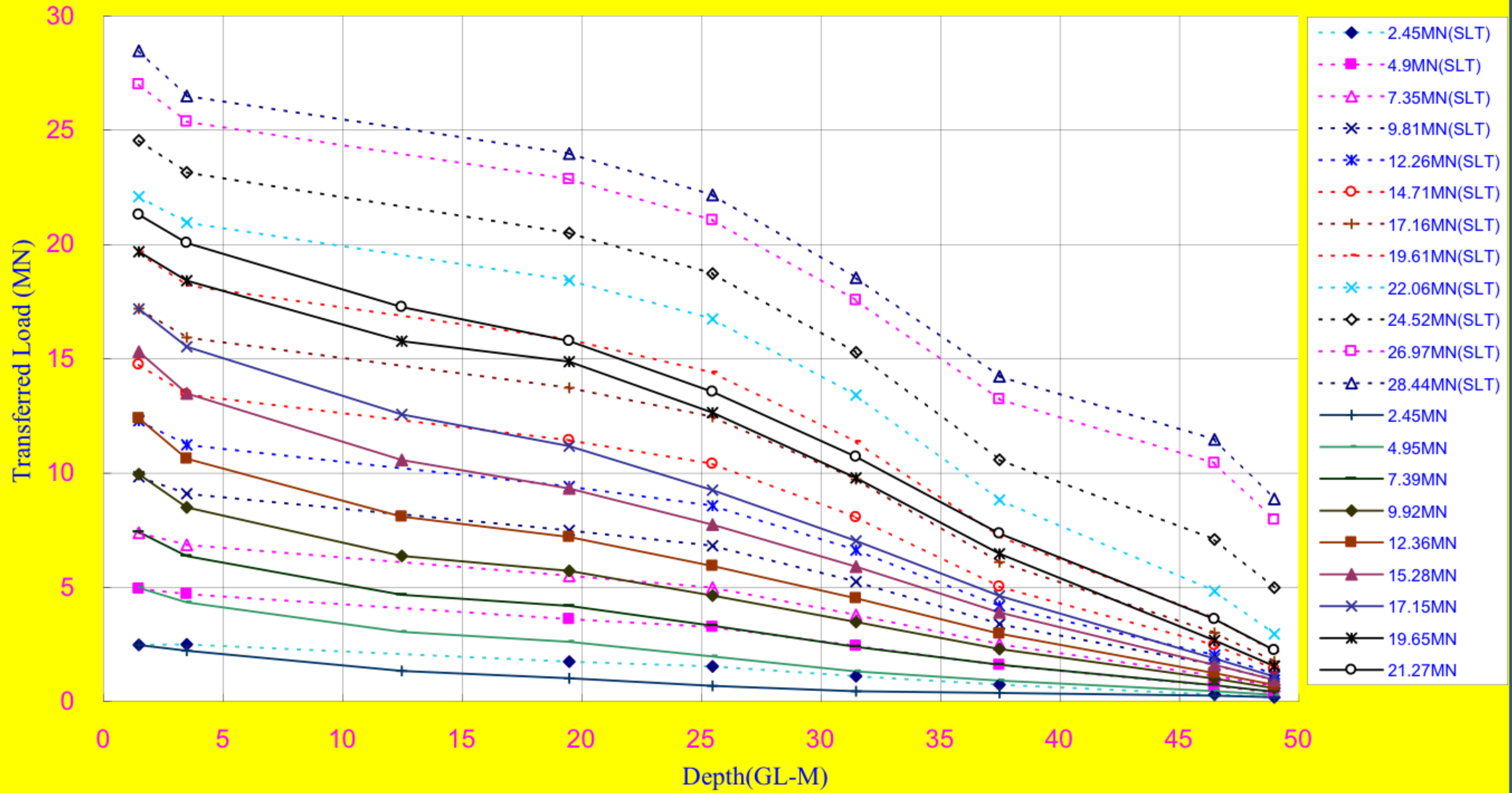
MALAYSIA


P&H
STATNAMIC
30 MN

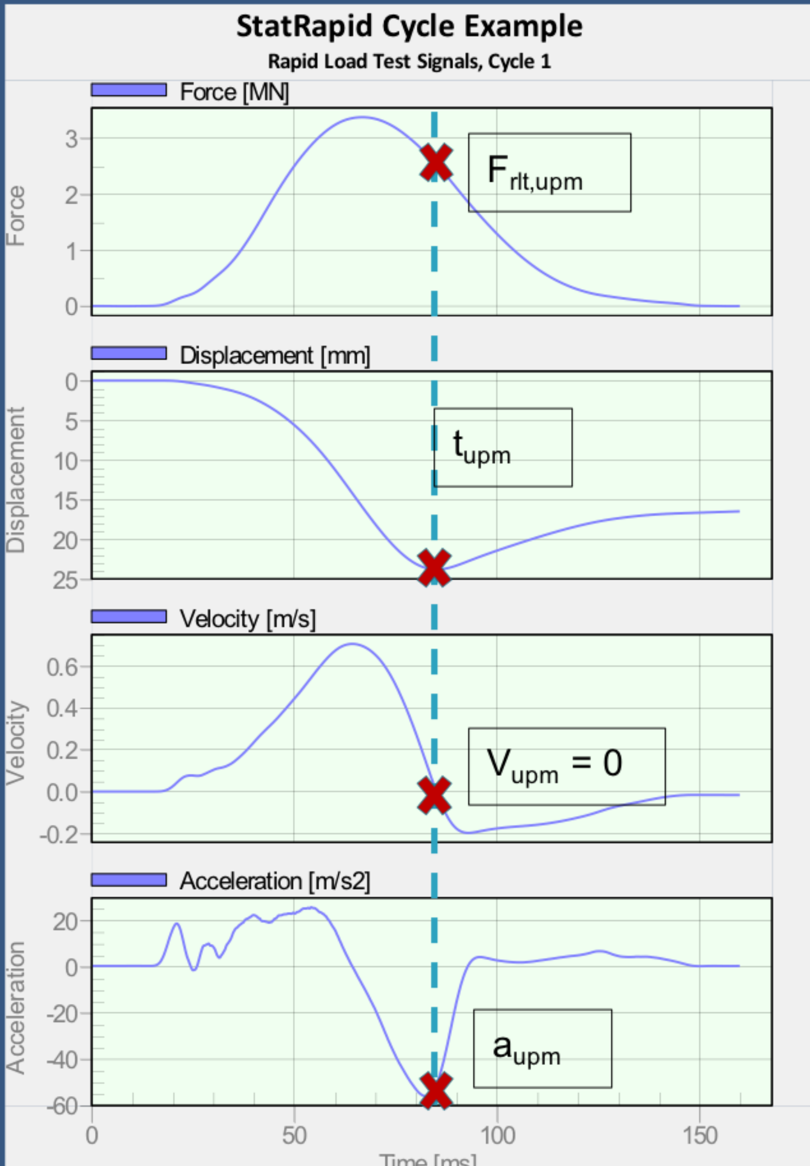
PREPARING THE PILE HEAD FOR A 30MN STATNAMIC TEST JOHOR BARU



Average Starin(micro strain)
200
150
100
50
0
GL-1.5m
GL-3.5m
GL-12.5m
GL-19.5m
GL-25.5m
GL-31.5m
GL-37.5m
GL-46.5m
GL-49.0m
0.98
1.00
1.02
1.04
1.06
1.08
1.10
1.12
1.14
Elapsed Time(second)



Transferred Load (MN)
Depth(GL-M)
0
5
10
15
20
25
30
35
40
45
50
2.45MN(SLT)
4.9MN(SLT)
7.35MN(SLT)
9.81MN(SLT)
12.26MN(SLT)
14.71MN(SLT)
17.16MN(SLT)
19.61MN(SLT)
22.06MN(SLT)
24.52MN(SLT)
26.97MN(SLT)
28.44MN(SLT)
2.45MN
4.95MN
7.39MN
9.92MN
12.36MN
15.28MN
17.15MN
19.65MN
21.27MN



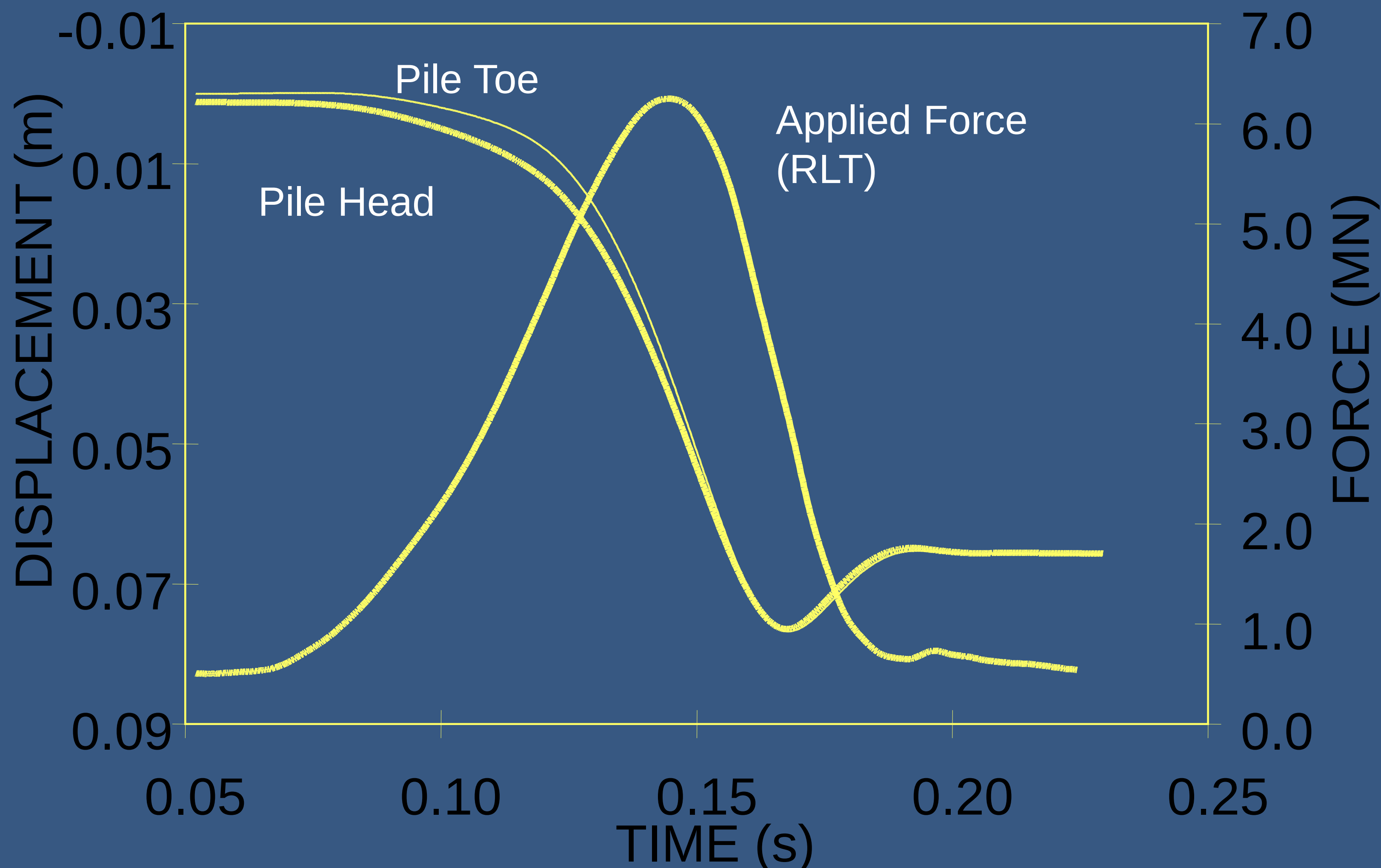
$$F_{static,upm,\ corrected} = (F_{rlt,upm} - (M_{pile} + M_{part}) \cdot a_{upm}) \cdot \eta$$

$$F_{static,upm} = F_{rlt,upm} - F_{inertia}$$

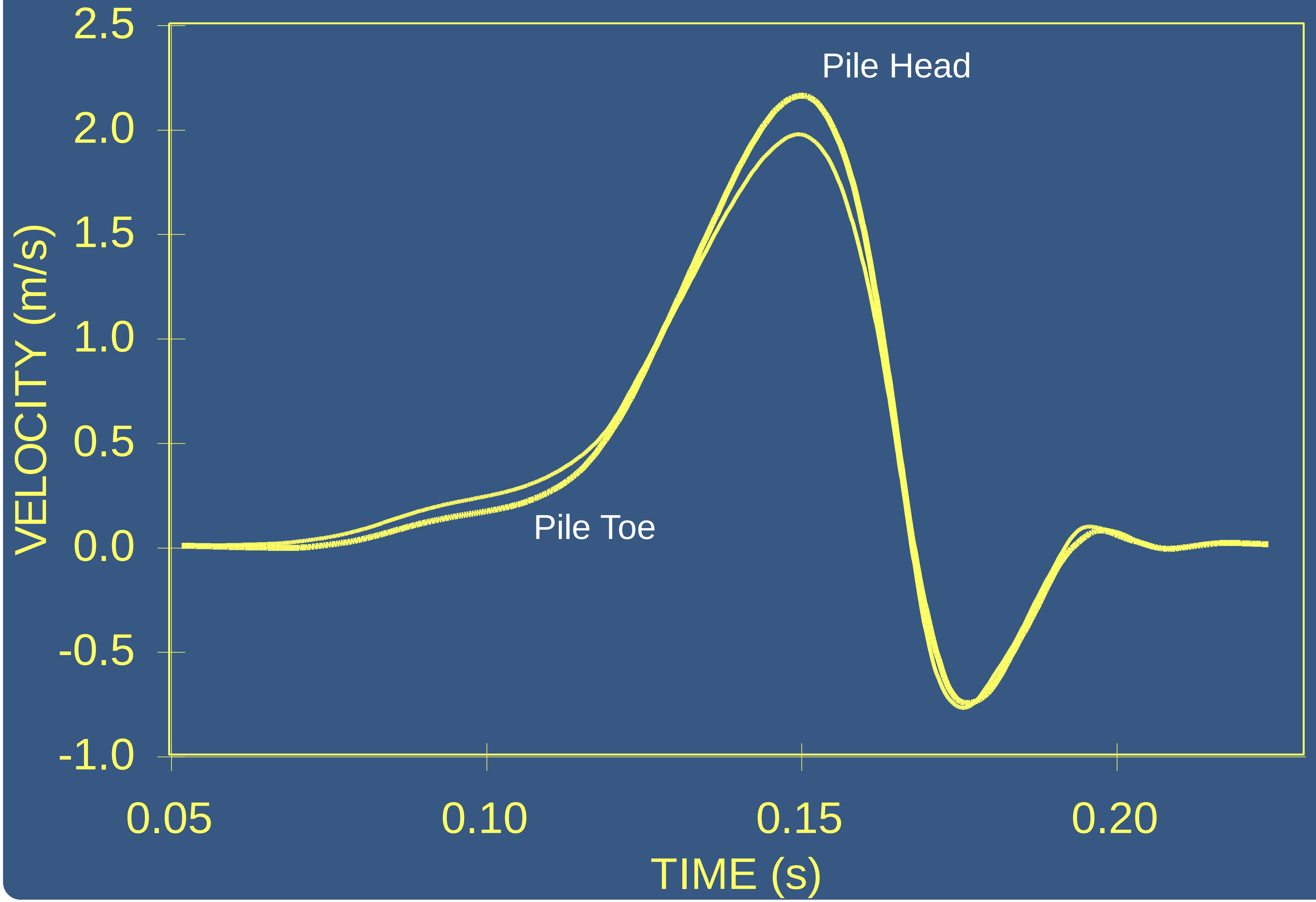
$$F_{inertia} = (M_{pile} + M_{part}) \cdot a_{upm}$$

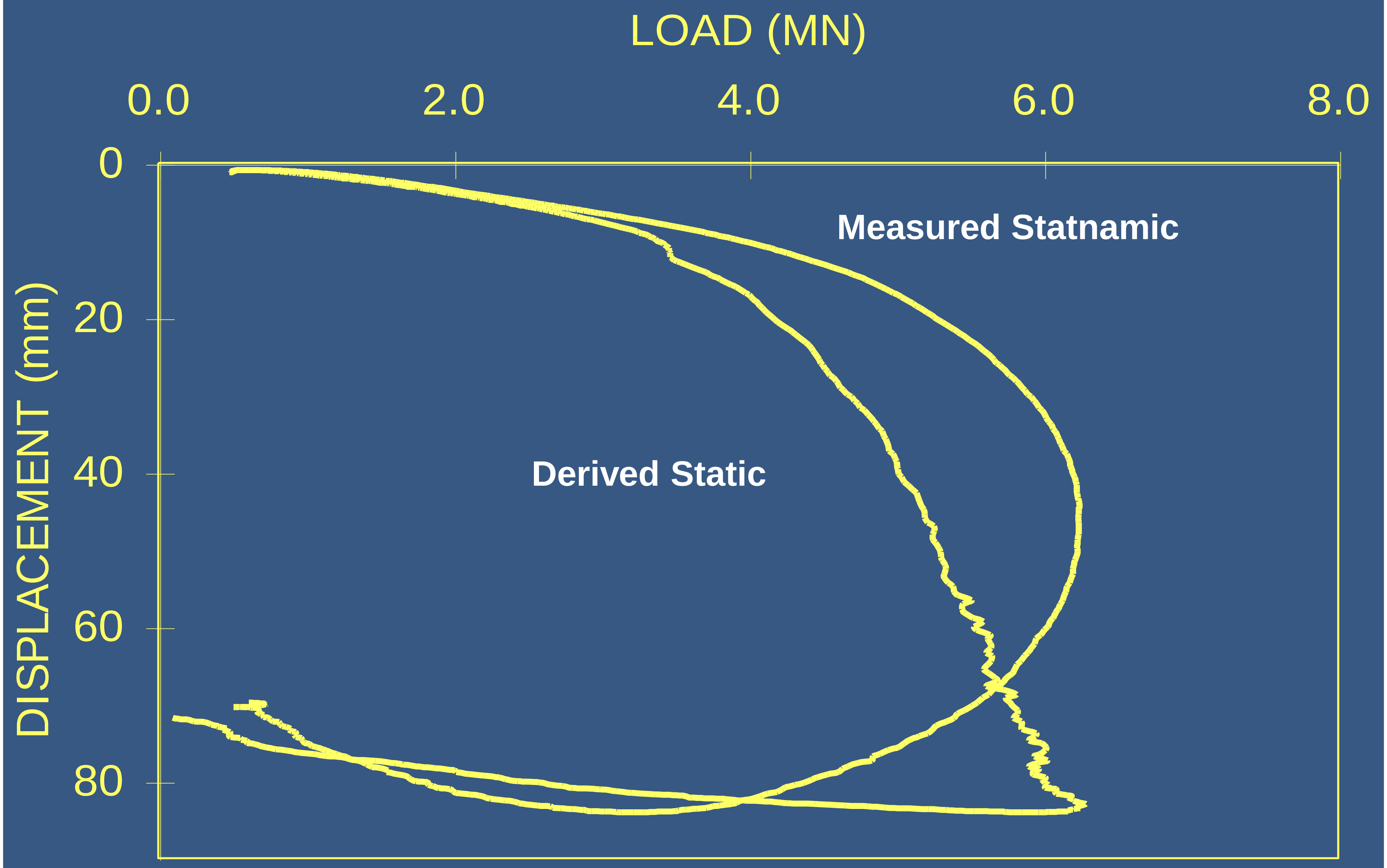
$F_{rlt,upm}$	= 2.53	MN
a_{upm}	= - 51.0	m/s^2
M_{pile}	= 8435	kg
M_{part}	= 3207	kg
M_{total}	= 8435 + 3207	kg
M_{total}	= 11642	kg
$F_{inertia}$	= 11642 x (– 51.0)	$kg.m/s^2$
$F_{inertia}$	=- 593742	N
$F_{inertia}$	= - 0.594	MN
$F_{static,upm}$	= 2.53 – (- 0.594)	MN
$F_{static,upm}$	= 3.12	MN
u_{upm}	= 23.8	mm
η	= 0.94	
$F_{static,upm}$	= 3.12	MN
$F_{static,upm,\ corrected}$	= 0.94 x 3.12	MN
$F_{static,upm,\ corrected}$	= 2.93	MN

Supporting evidence…stress waves?



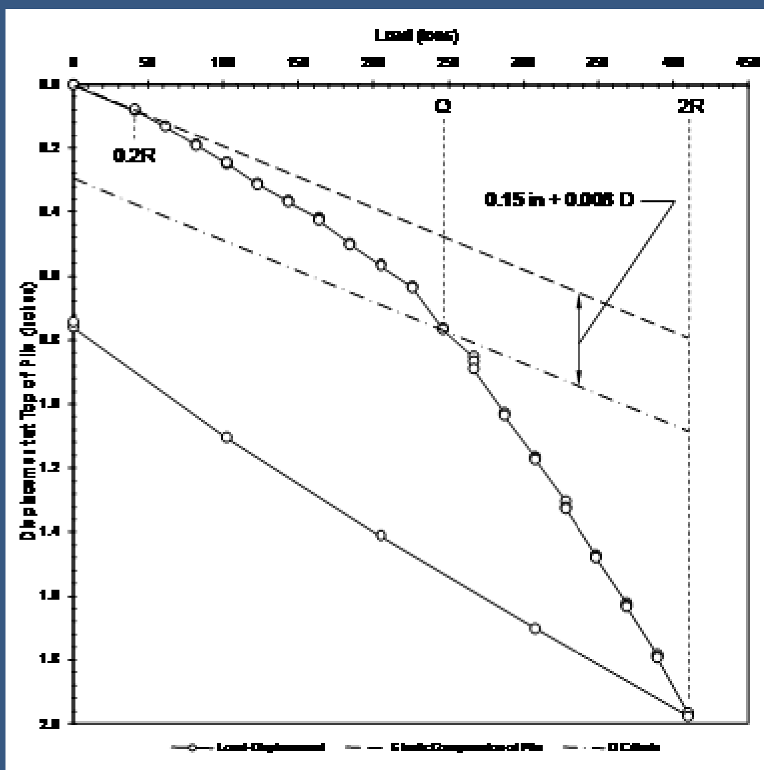
Supporting evidence…stress waves?

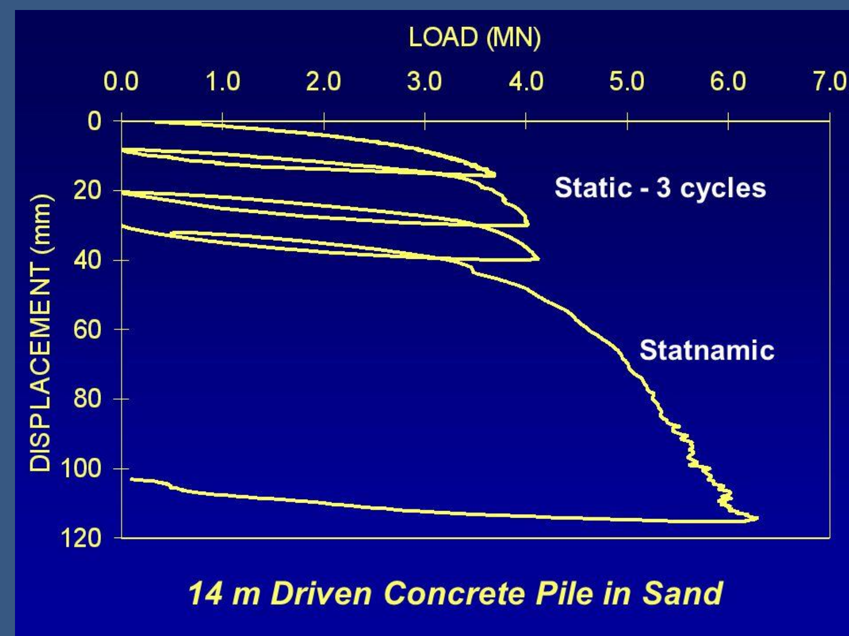


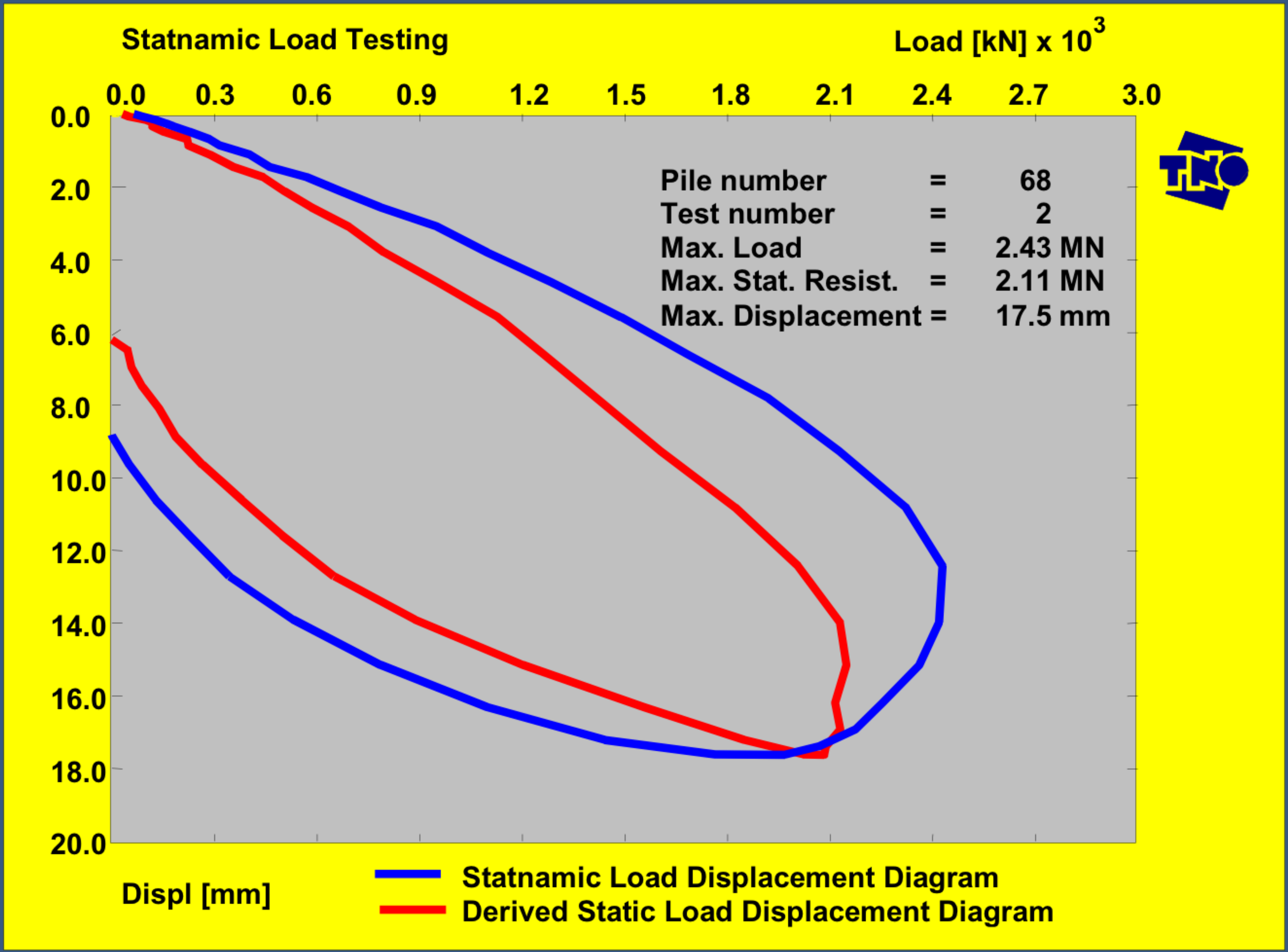


"Derived Static" from Statnamic

LOAD SETTLEMENT CURVE

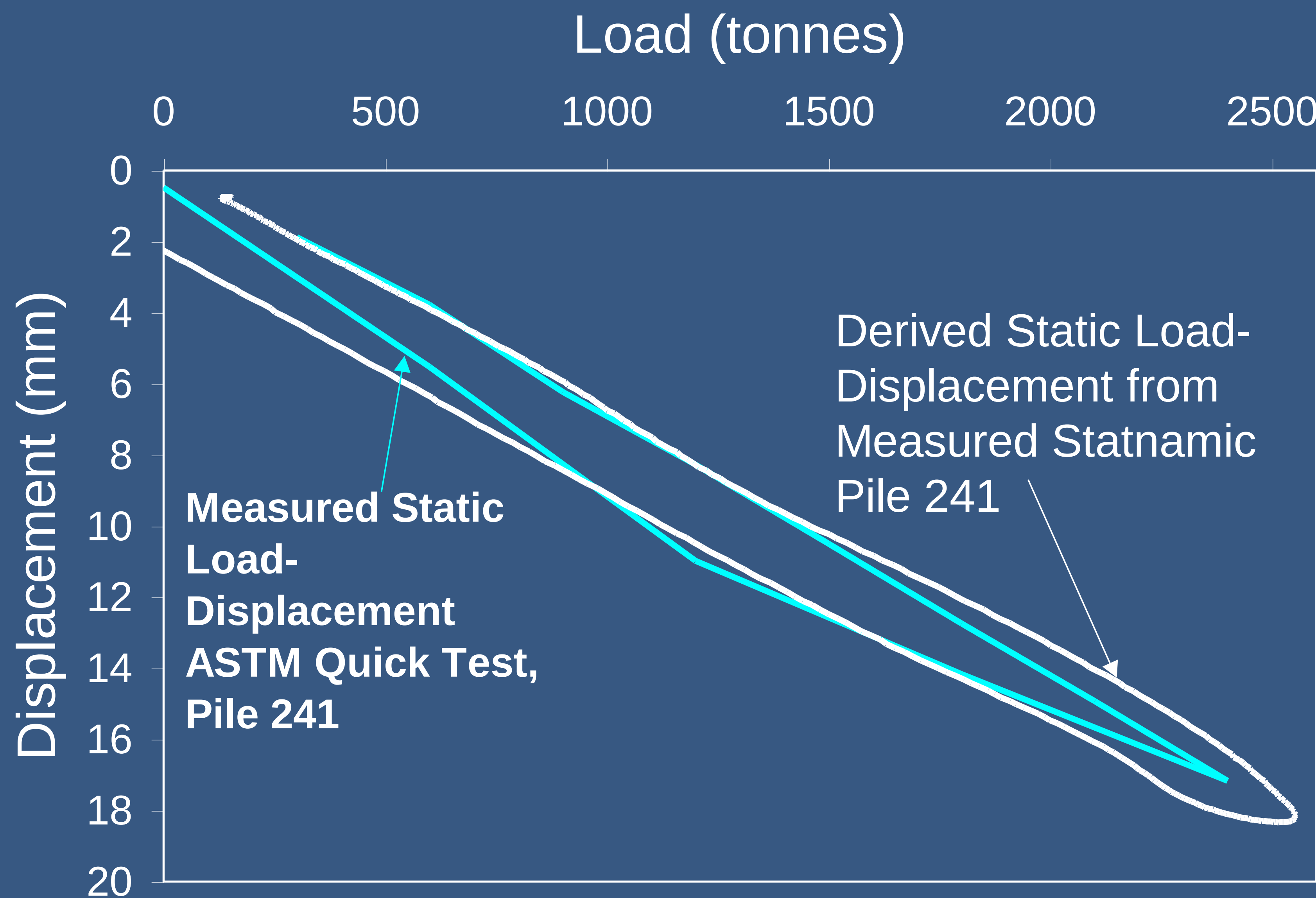






Statnamic Load Testing
Load [kN] x 10^3
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 3.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
Pile number = 68
Test number = 2
Max. Load = 2.43 MN
Max. Stat. Resist. = 2.11 MN
Max. Displacement = 17.5 mm
Displ [mm]
Statnamic Load Displacement Diagram
Derived Static Load Displacement Diagram

Static Load Test (SLT) Taipei


Load (tonnes)
0
500
1000
1500
2000
2500
Displacement (mm)
0
2
4
6
8
10
12
14
16
18
20
Derived Static Load-Displacement from Measured Statnamic Pile 241
Measured Static Load-Displacement ASTM Quick Test, Pile 241

FHWA LATERAL TEST TO 5, 6 & 8 MN

PYRODRIVER (UNDERWATER HAMMER)

TESTING OFF THE COAST OF EQUATORIAL GUINEA AT OF 437M

RELIABLE MEANS OF DIRECTLY MEASURING THE LOAD SETTLEMENT BEHAVIOR OF A PILE FOUNDATION

- Not a prediction method.
- Not an estimate.
- Not subject to operator influence

MECHANICAL CATCHING MECHANISM

RAPID LOAD TESTING (STATRAPID DEVICE)

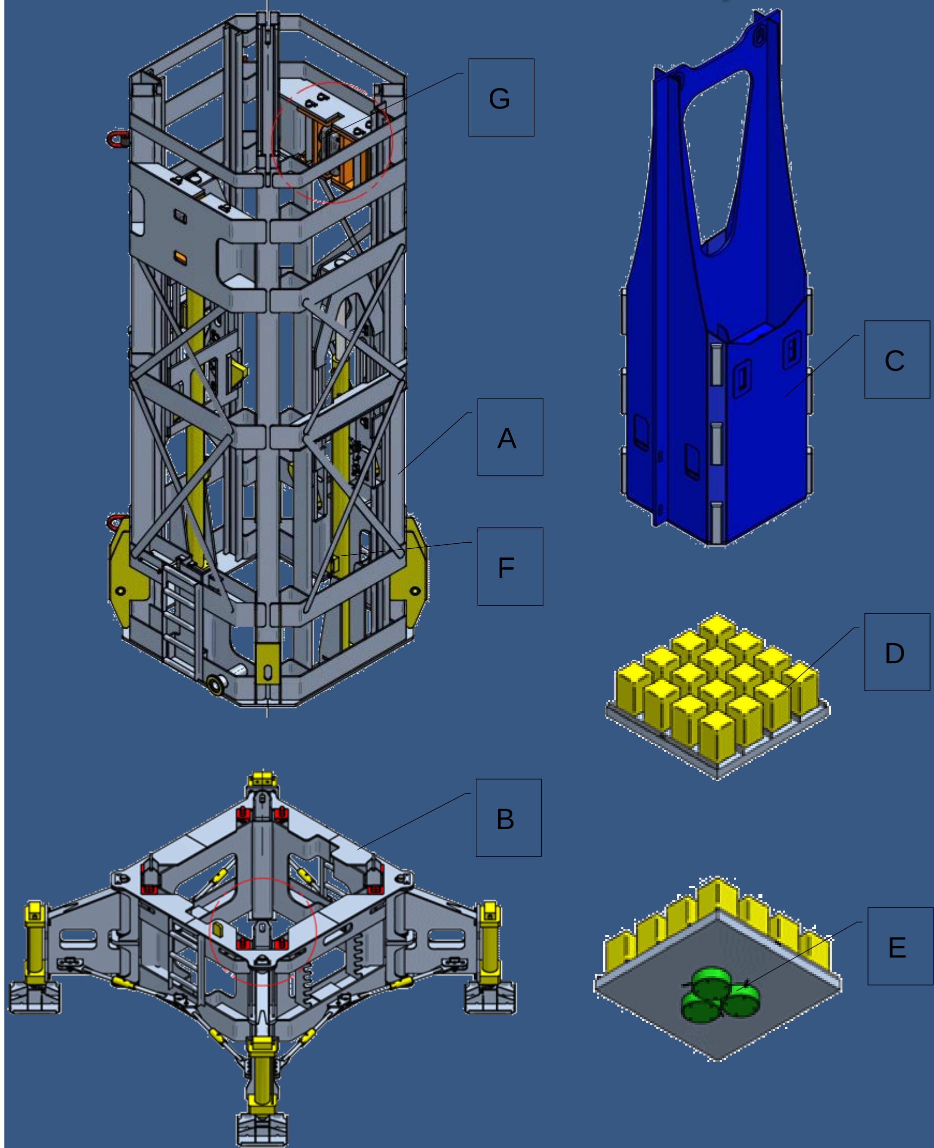
There is a growing awareness that pile capacities determined by signal matching techniques heavily depend on the assumptions made by the person analyzing the test results and yield a wide range of results, especially for cast in situ piles

Consequently it is virtually impossible to calibrate these signal matching based methods against static load tests, since calibration requires consistent results for each method.

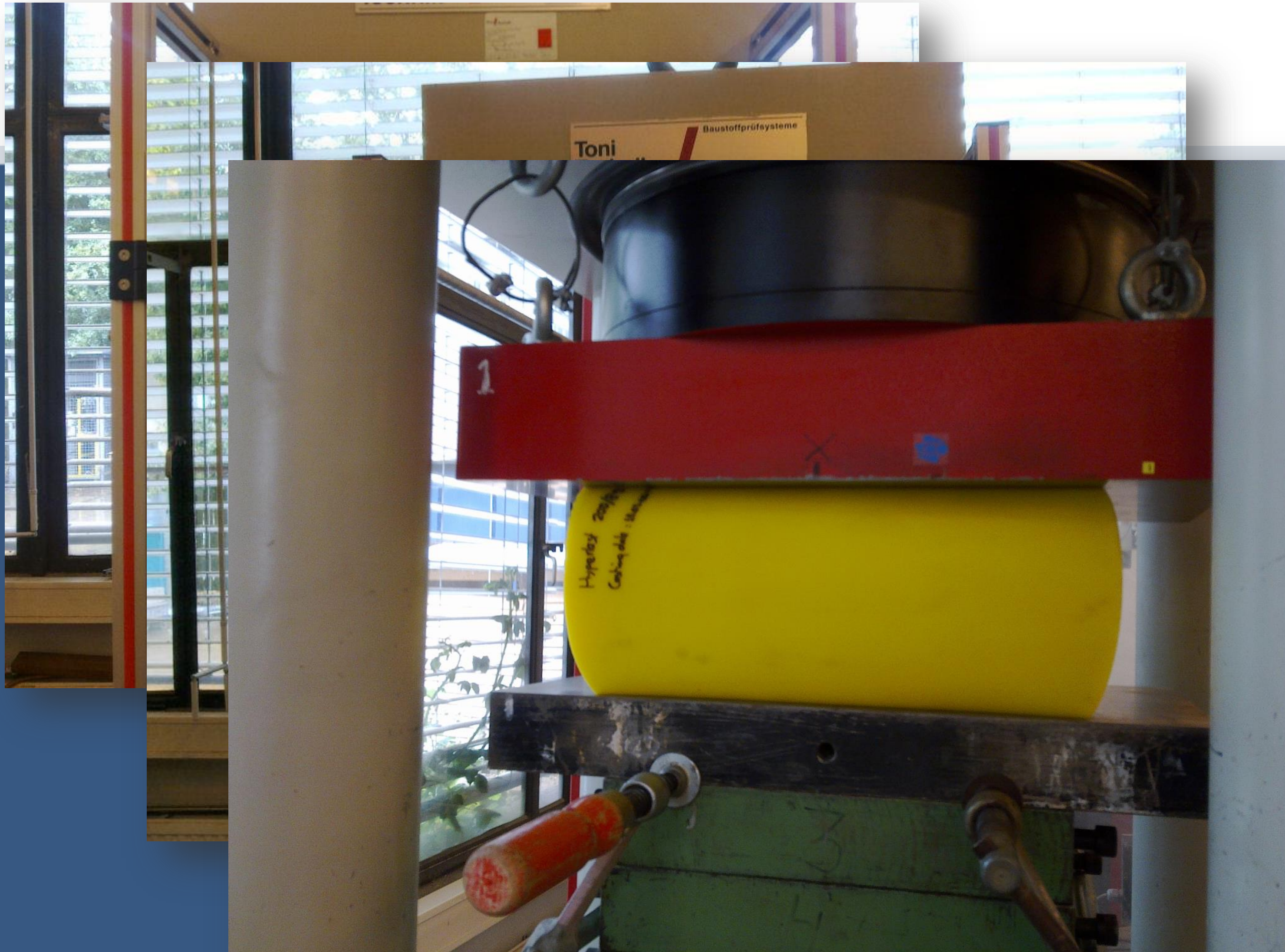
This is one of the reasons that in 2010 the Dutch CUR commission adopted the Rapid Load Testing technique (over the high strain dynamic testing) as the results are consistent and virtually independent of the person analyzing the test data.

(8 MN StatRapid Device, modular drop weight up to 40 tons)

The StatRapid Components (STR)



A – Upper frame
B – Bottom frame with hydraulic adjustable legs to adjust frame inclination
C – Container with modular drop weight s (0.2 MN – 0.4 MN – 0.8 MN)
D – Rubber springs (stiffness can be adjusted)
E – Impact plate with load cells
F – Internal lifting tool for adjusting drop height
G – Brake system for catching and releasing the drop mass.



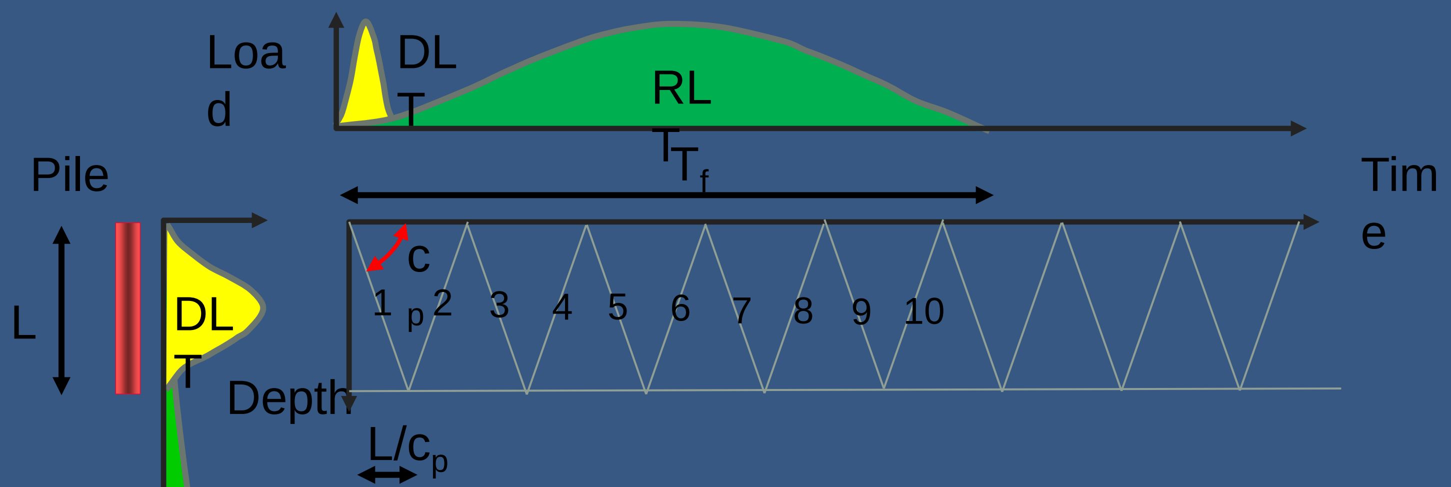
STAT RAPID

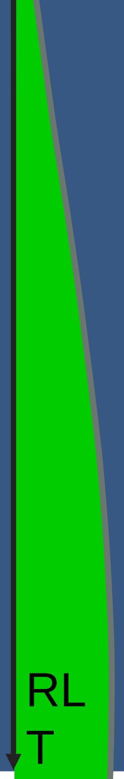
STATNAMIC

Allnamics.com


ARCO AVON

Requirements for RLT



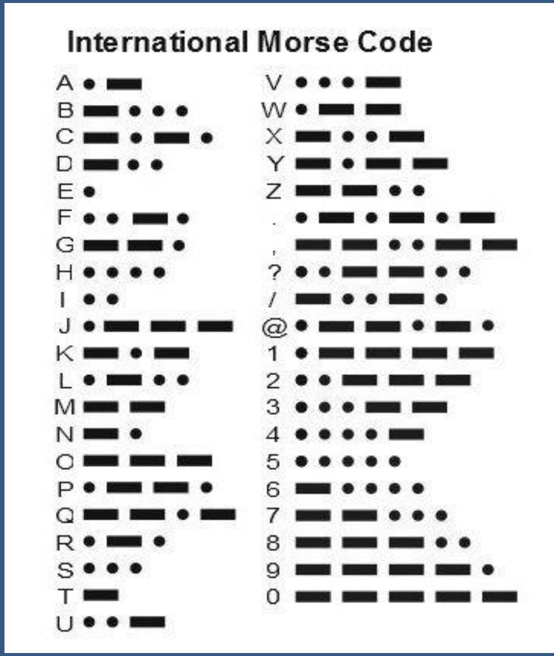


Requirement for RLT

$$10 \prec \frac{T_f}{L/c_p} \le 1000$$

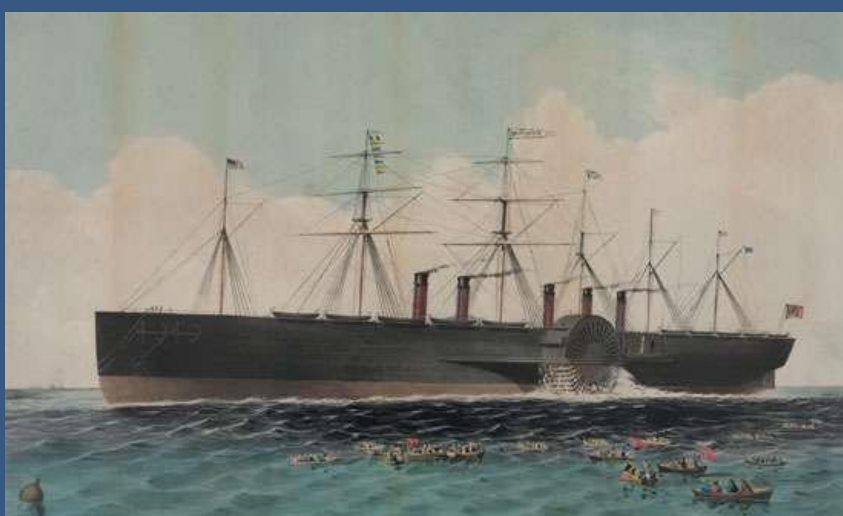
T_f = Load duration(s)
L = Pile lengthe (m)
c_p = stress wave velocity pile material (m/s).

SAMUEL MORSE
ARTIST, TRAVEL, VACATION



ISAMBARD KINGDOM BRUNEL

SCALE AND CONFIDENCE



CONCLUSIONS

- Rapid Load Testing (RLT) is an accurate means of measuring the load displacemt behavior of Foundations
- Statnamic has revealed many spectacular foundation failures across the globe
- The test is not operator dependent.
- Shaft friction distribution for RLT is similar to static load testing

2.4257 M/s

3.4304 M/s

THE VIS VIVA RESULTS!! E= M X V^2

60cm drop height

30cm drop height

STATNAMIC THE HISTORY OF THE IDEA

Thank you for your attention!