PROVE IN SITO - LABORATORIO PROVE MATERIALI
4 EMME SERVICE S.p.A. - 39100 BOLZANO - ITALY - Via L. Zuegg, 20

"CASE" DYNAMIC LOAD TESTING ON PILES

PILOT PILES AT XXXXXXXXXXXXX

LAGOS - NIGERIA

Test No. 001/PO ÷ 002/PO

16-17 January 2014

Consigner: **XXXXXXXXXXXXX**

Supervisor: **Eng. Thomas Vassalli**

View of the site

Ref: PO-101-13

Bologna, 31 January 2014

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1. INTRODUCTION

The company *4 EMME Service S.p.a.*, specialized in performing experimental tests on structures on site, has been asked by XXXXXXXXXX to perform 2 high strain dynamic load tests on foundation piles at their site in Lagos, Nigeria.

The test methods and the piles to be tested have been agreed on in advance with the Consignor.

The tests were performed on 16/17 January 2014.

The following people were present for the tests:

Eng. XXXXXXXXXX	XXXXXXXXXX
Eng. XXXXXXXXXX	XXXXXXXXXX
Eng. XXXXXXXXXX	XXXXXXXXXX
Eng. XXXXXXXXXX	XXXXXXXXXX

and on behalf of *4 EMME Service S.p.a.*:

Eng. Thomas Vassalli.

2. HIGH STRAIN DYNAMIC LOAD TESTS

The "Case" method, in accordance with ASTM D4945-08, is known as the high strain dynamic load test and is the technique used to test the load-bearing capacity of deep foundations in limit operating conditions as indicated in NTU - Ministerial Decree 14/1/08, paragraphs 6.4.3.7.1-2.

2.1. Test procedure

The high strain dynamic load test is performed by applying an axial load to the top of the pile through the impact of a mass weighing approximately 1% of the test load to be reached, which is dropped from a maximum height of 1.2 m, producing enough energy to test the resistance of the pile-soil system.

The data on force and acceleration induced in the pile is recorded and then processed by CAPWAP (*Case Pile Wave Analysis Program*) software.

This method compares test data with a numeric model of the pile-soil system. In the analysis, the soil is schematized as a plastic medium and the pile is considered a system of perfectly elastic and equal finite elements. Using the force and speed values from the test, the total resistance (R_t) is calculated using the following equation:

$$R_t(t^*) = \frac{1}{2}\left[F_m(t^*) + F_m\left(t^* + \frac{2L}{c}\right)\right] + \frac{Mc}{2L}\left[v_m(t^*) - v_m\left(t^* + \frac{2L}{c}\right)\right]$$

where:

t^* = time after impact of max. system resistance;

F_m = vertical force measured by instruments at time t^*;

v_m = velocity of particles measured in test;

c = transmission speed of mechanical waves;

M = pile mass;

L = pile length.

To provide a model which is sufficiently representative of the real situation, the total resistance is divided into a static component (R_s) and a dynamic component (R_d) using the following equation:

$$R_t = R_s + R_d$$

The dynamic component can be calculated using a viscous soil damping constant J from published test tables. The following equation is used to determine said component:

$$R_d = J \cdot v_t$$

where v_t is the velocity at the base of the pile.

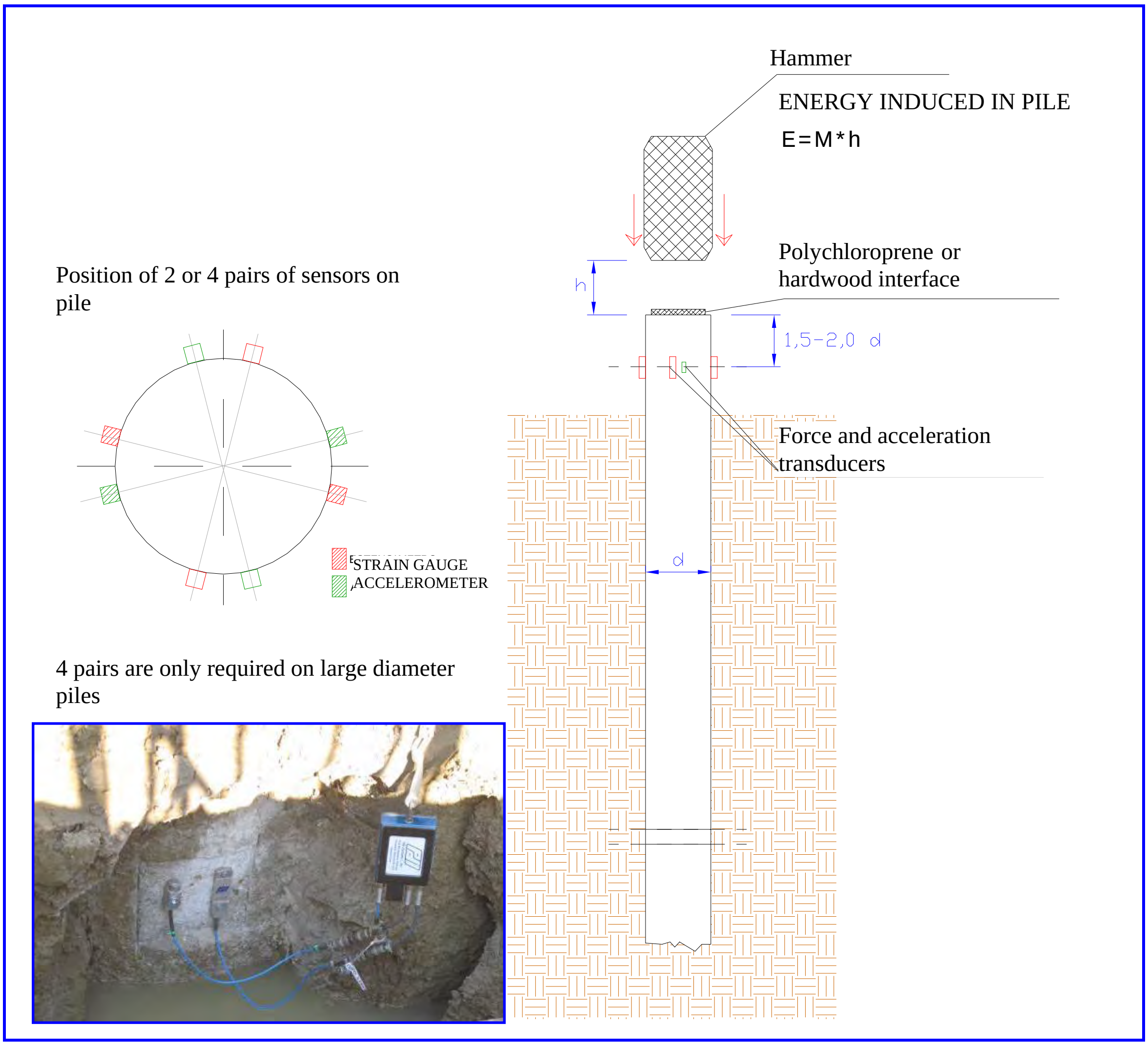
Using the above equations, the static resistance R_s of the pile can be calculated.

The Case Method, using the CAPWAP program provides an estimate of the ultimate pile strength with a certainty of around 10%, compared to static test results.

A great deal of information can be found on this method on the web site www.4emme.it under GENERAL BIBLIOGRAPHY.

2.2. Test procedure

- Pile prepared to create a flat, even surface at the top where the stress can be applied (in this case the isolated footing);
- installation of two pairs of diametrically opposed sensors (accelerometers and strain gauges), on a flat area of the pile at a depth roughly 1.5 times the pile diameter;
- sclerometric tests performed on two levelled surfaces to determine the mechanical strength of the concrete;
- configuration of the equipment with the geometric and mechanical parameters of the pile;
- a series of stress impulses are applied to the pile by dropping the mass from heights increasing by 10 cm each time until the pile is put under a stress greater than that to be tested;
- creation of a pile-soil numeric model using the CAPWAP system and calibration of the analytic values using the test data.



Test diagram

2.3. Description of the equipment

2.3.1. M3200 hydraulic pile hammer

A hydraulic pile hammer will be used to induce axial stress on the piles, raising and instantaneously releasing a steel weight.

The equipment drops the cylindrical weight from various heights up to a maximum height of 100 cm. The system is controlled by a hydraulic power plant.

The hammer consists of a steel cup weighing 50 kN in which up to 15 additional weights weighing 18 kN each can be inserted, bringing the maximum weight of the hammer up to 320 kN.

A 3 cm-thick polychloroprene disc is placed between the weight and the top of the pile to produce a uniform impact.

Characteristics of the M3200 Pile Hammer

Hammer	320.0 kN
Overall weight	n.d.
Maximum drop height	100 cm
Imprint size	80 cm
Overall diameter	n.d.
Closed height	approximately 900 cm

2.3.2. Measuring system

A pair of diametrically opposed strain gauges and accelerometers, installed at a depth of approximately 1.5 times the diameter of the top of the pile are used to measure the force and acceleration induced in the pile.

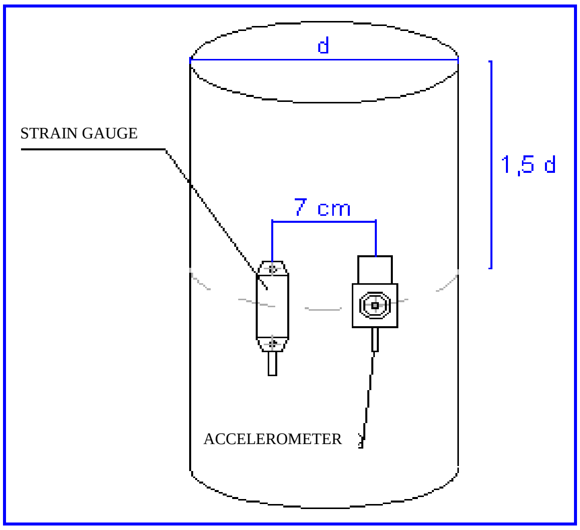
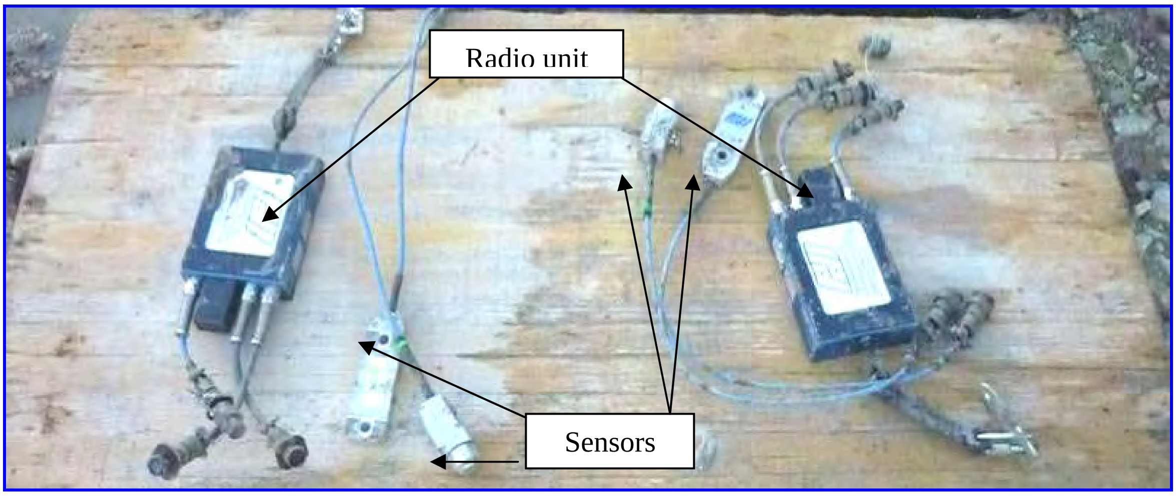


Diagram showing the position of the sensors

The following are installed:

- 2 piezoresistive accelerometers (measuring range 1.0 ÷ 5000 g);
- 2 strain gauge sensors with eight ½ bridge strain gauges in series;
- 2 wireless transmission units.



Accelerometer, strain gauge sensors and two wireless transmission stations

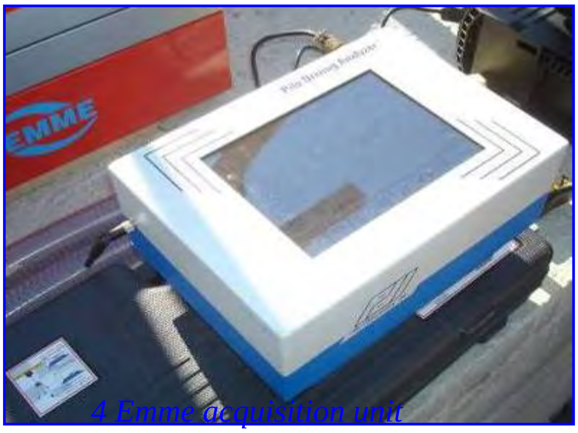
All the instruments are periodically checked as required by procedure 7.6 "Instrument Management" of the Quality Manual.

The strain gauges and accelerometers communicate with the PDA acquisition unit through a wireless unit.

Note: For educational purposes only, in parallel, an identical measurement is taken using the Consignor's equipment.

The system can communicate with the sensors installed on the pile, to record and process the signals to provide output parameters in real time:

- max. force transmitted to pile;
- max. displacement of pile top;
- indicative value of total resistance of pile-soil system moved during stress calculated using Case Method.



4 Emme acquisition unit

Acquisition unit - Trevi

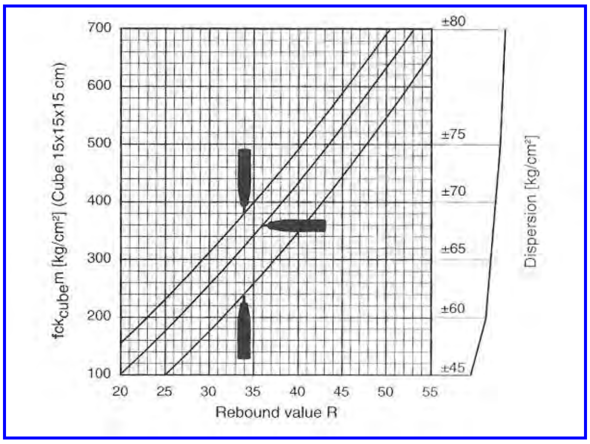
Accelerometer and strain gauge sensors

Power plant + Notebook

Direct sensor connection

2.4. Determining the mechanical properties of the concrete

A sclerometric test was performed on the part of the pile free of soil to determine the mechanical properties of the concrete. In detail, a series of impact tests were performed on the two levelled faces where the sensors are installed.



Instruments used

The mechanical strength calculated is used to estimate the Elastic Modulus on the basis of the normative formula:

$$E = 22000\ (R_{cm}/10)^{0,3}\quad [MPa]$$

This value, obtained in the field, improves acquired signal processing and as a consequence also the evaluation of the pile load-bearing capacity. Standard *UNI-EN 12504-2* was referred to for the test.

Values	PILE 1
Ir Value Face A	40 – 38 – 42 – 44 – 40 – 36 – 42 – 40 – 40 – 36 – 42
Ir Value Face B	36 – 42 – 40 – 38 – 42 – 44 – 40 – 40 – 36 – 40 – 38
Average Ir Value Face A	40.0
Average Ir Value Face B	39.6
Rmc (MPa)	(40.0+39.6)/2 = 39.8
Elastic Modulus (MPa)	34,922

Values	PILE 2
Ir Value Face A	40 – 38 – 42 – 44 – 40 – 36 – 42 – 40 – 40 – 36 – 42
Ir Value Face B	36 – 42 – 40 – 38 – 42 – 44 – 40 – 40 – 36 – 40 – 38
Average Ir Value Face A	40.0
Average Ir Value Face B	39.6
Rmc (MPa)	(40.0+39.6)/2 = 39.8
Elastic Modulus (MPa)	34,922

2.5 Characteristics of the test piles

The tests were performed on concrete Continuous Flight Auger (CFA) bored piles with the following characteristics:

Test No.	Date test	Column No.	Diameter [cm]	Length [m]*	Working load [kN]	Test load [kN]
001/PO	16-17/01/14	1	60	18.0	1,000	3,000
002/PO	17/01/2014	2	80	18.0	1,600	4,800

** the length indicated is that of the pile, without the extension of roughly 1.2 m.*

3. TEST RESULTS

The values obtained during the various readings are shown below.

Pile 1

Phase	H (cm)	Fmx (kN)
1	10	1,164
2	20	1,479
3	30	2,752
4	40	3,223
5	50	3,645

Pile 2

Phase	H (cm)	Fmx (kN)
1	10	-
2	20	-
3	30	4,911
4	40	5,095
5	50	8,675

The following pages show the diagrams with the values obtained from the pile-soil numeric model using the *CAPWAP* system.

DYNAMIC LOAD TESTING ON PILES

Test:	**001/PO**	Instrument:	PDA Model Pax-8
Site:	XXXXXXXXXXX		
Location:	Lagos (Nigeria)		
Date:	16/01/2014	Tester:	Eng. Thomas Vassalli
Structure:	-	Data dev.:	Eng. Thomas Vassalli

Pile characteristics

Pile No.: 1
Type: bored
Material: concrete
C_e= 1000 kN
L = 18.0 m
D = 60 cm
L_E = 18.4 m
L_P = 18.0 m

Sensors used

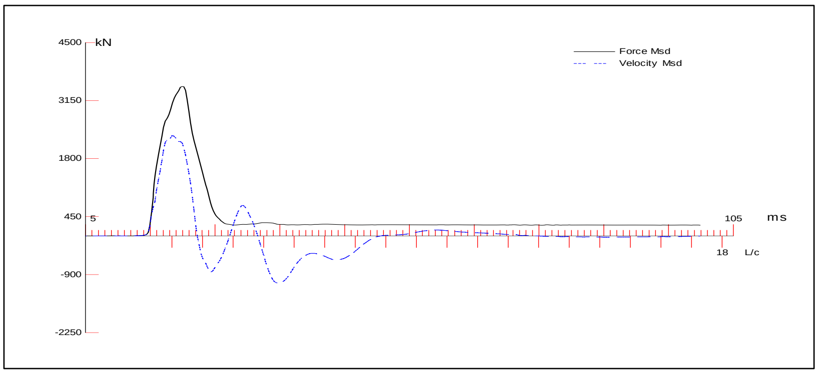
No. Strain gauges: 2
No. Strain gauges: 2
Position: diametric
Connection: wireless

Pile hammer used

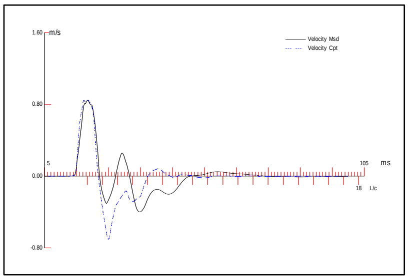
Model: M3200
Mass: 50.0 kN
maximum h: 100 cm
Imprint D: 80 cm
Overall D: n.d. cm
Controls: radio

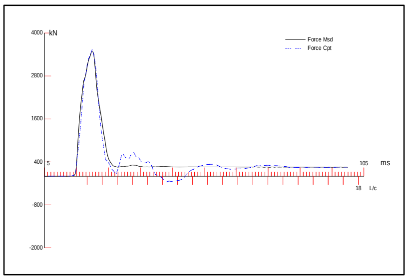
Measurements

R_{mc} = 39.8 MPa
E = 34922 MPa

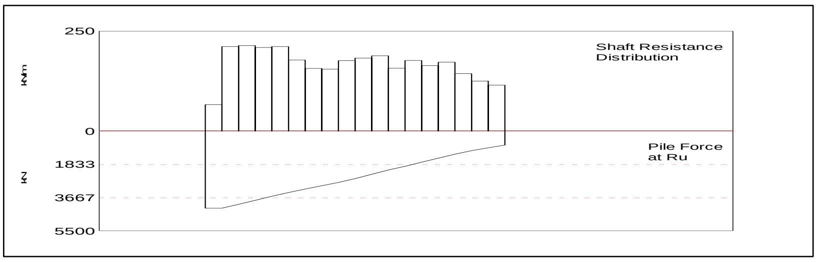


Force – Velocity/Time





Force Calibration *Velocity Calibration*



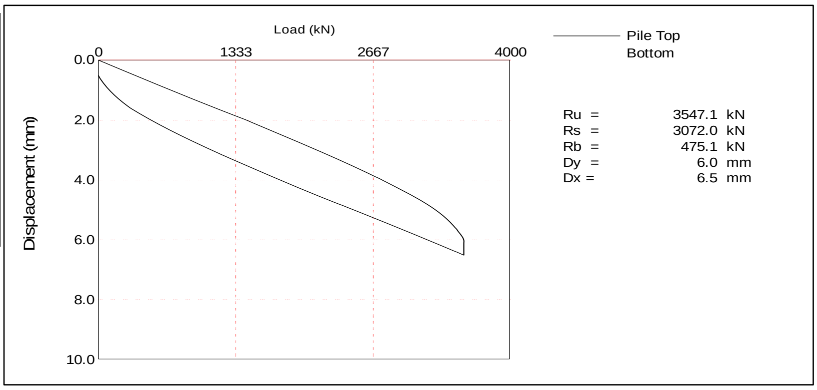
Resistance Distribution

Dynamic test

Phase	h [cm]	Δ [mm]	F_{MX} [kN]
1	10	1.85	1,164
2	20	6.17	1,479
3	30	3.64	2,752
4	40	4.25	3,223
5	50	5.03	3,645

Results

F_{MX} =	3,645 kN
Rs =	3,072 kN



Load diagram – Yield

DYNAMIC LOAD TESTING ON PILES

Test: 002/PO
Site: XXXXXXXXXXX
Location: Lagos (Nigeria)
Date: 16/01/2014
Structure: -

Instrument: XXXXXXXXXXXXXXXX

Tester: Eng. Thomas Vassalli
Data dev.: Eng. Thomas Vassalli

Pile characteristics

Pile No.: 2
Type: bored
Material: concrete
C_e = 1600 kN
L = 18.0 m
D = 80 cm
L_E = 18.4 m
L_P = 18.0 m

Sensors used

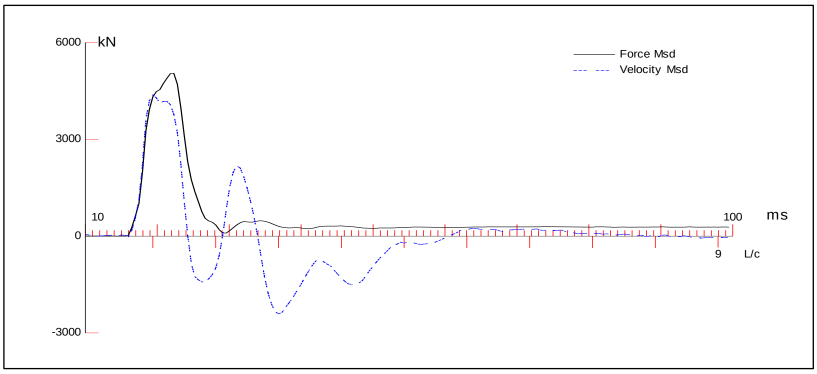
No. Strain gauges: 2
No. Strain gauges: 2
Position: diametric
Connection: cable

Pile hammer used

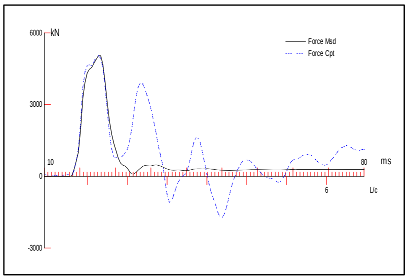
Model: M3200
Mass: 50.0 kN
maximum h: 100 cm
Imprint D: 80 cm
Overall D: n.d. cm
Controls: radio

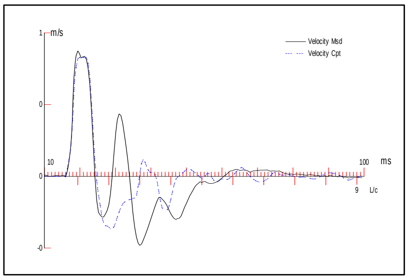
Measurements

R_{mc} = 39.8 MPa
E = 34922 MPa

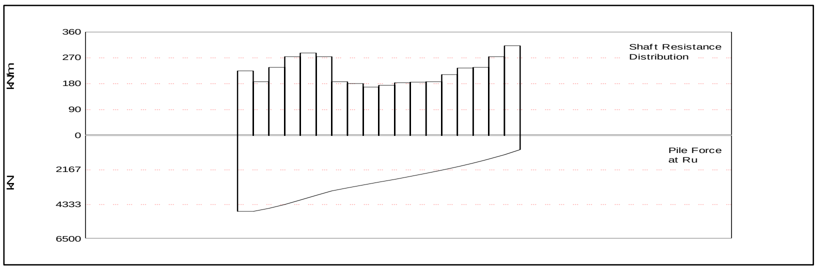


Force – Velocity/Time





Force Calibration *Velocity Calibration*



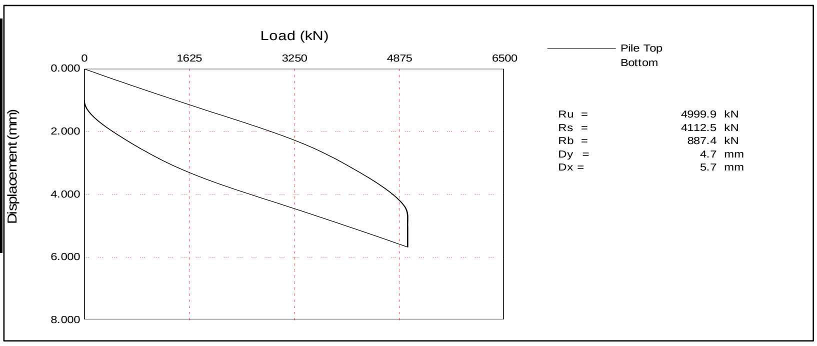
Resistance Distribution

Dynamic test

Phase	h [cm]	Δ [mm]	F_{MX} [kN]
1	10	-	-
2	20	-	-
3	30	2.50	4,911
4	40	3.18	5,095
6	50	3.27	8,675

Results

F_{MX} =	8.675 kN
Rs =	4,112 kN



Load diagram – Yield

The following symbols are used for the Case test parameters:

Ce = working load
L_E = sensor height – pile bottom
L_P = distance of excavation – pile bottom
h = weight dropped from (height)
Δ = max. deformation
R_{mc} = average resistance of concrete
E = elastic modulus of concrete
F_{MX} = vertical force applied
S = pile top dropped
R_u = total ultimate strength
R_u = lateral ultimate strength
R_b = peak load
D_y = max. load deformation
D_x = final max. deformation

All the data in the tables and graphs was obtained from files saved during the tests.

Bologna, 31 January 2014

Tester
Eng. Thomas Vassalli

4 EMME Service S.p.a.
Eng. Settimo Martinello