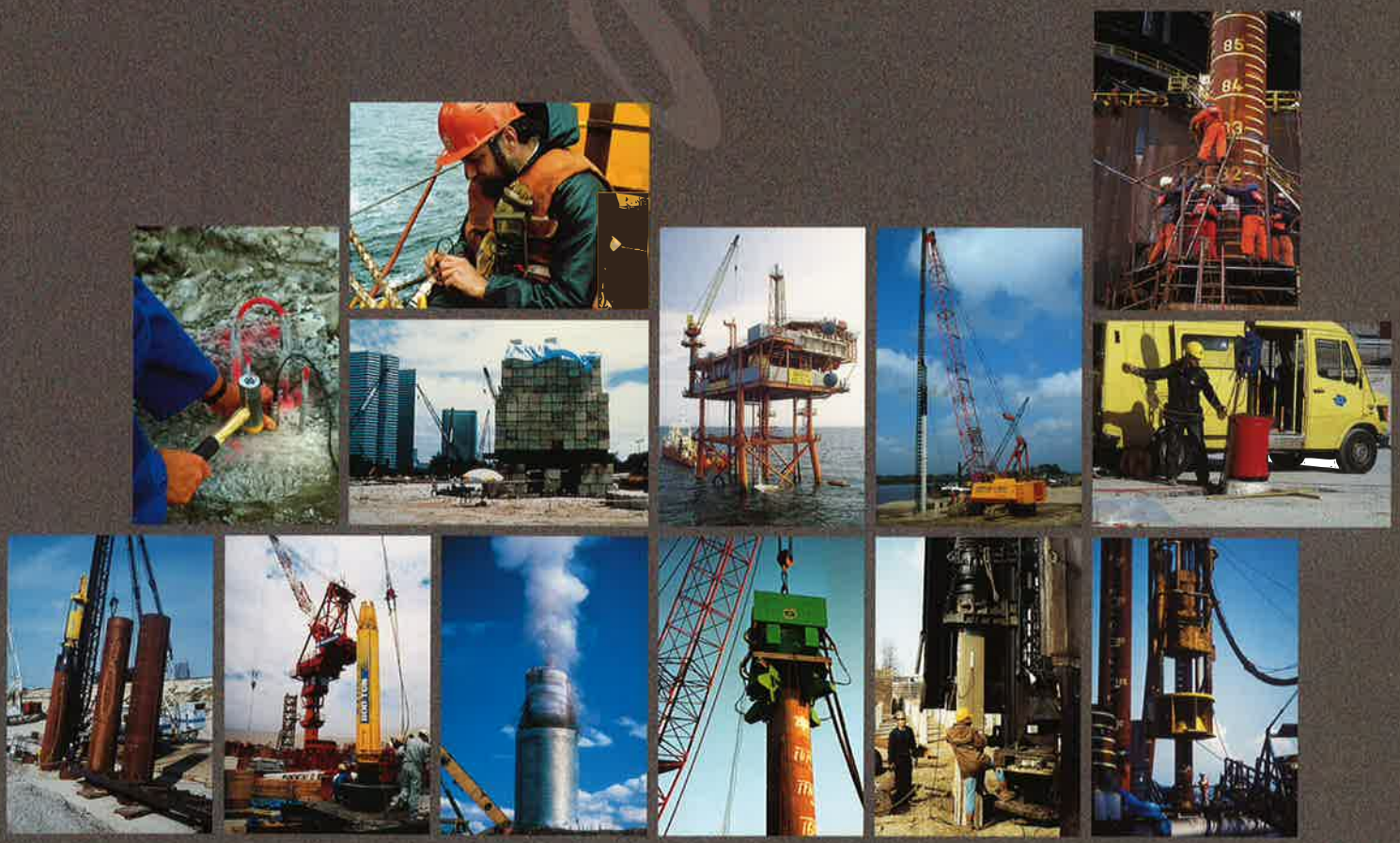
TNO Building and Construction Research

Foundation Pile Diagnostic Systems



Improve your competitive power

Foundation Pile Diagnostic System
FPDS-6 KIT

Pile Testing Equipment with Multiple Applications

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

What is FPDS-6 KIT ?
FPDS-6 KIT represents a new approach to foundation testing equipment. It can replace all existing FPDS equipment made by TNO and others. FPDS-6 KIT is a hardware/software package that is designed to work with a wide range of PC (IBM compatible) computers equipped with a PCMCIA slot. Multiple testing and monitoring applications are available. For most applications FPDS-6 KIT consists of a PCMCIA card incorporating all data acquisition and signal conditioning electronics, cables, sensors and application software.
This means that the data acquisition electronics are placed on a card measuring 8.5 cm by 5.5 cm, and 3 mm thick!
Aside from the space and weight savings, this innovation dramatically increases overall system reliability and service life. A limited number of applications will still only be available with external data aquisition or signal conditioner units.

FPDS-6 KIT is best used in combination with hand-held PC's, such as the Texas Micro Hardbody™ PC. Hand-held PC's are a new generation of PC's, which are extremely powerful yet can be rugged; capable of working in even the most extreme of field environments. The computer chosen must have roughly the same technical specifications as the Texas Micro Hardbody™ PC.

A major advantage of FPDS-6 KIT is the ability to run multiple applications with the same computer system. Each application comes with English manuals and training courses.

Easy to use operation
FPDS-6 KIT software is menu driven and easy to use. Knowledge of electronics is not necessary - all electronic functions are controlled by the computer. Advice and warnings are generated by the system when required. Signals and other data are stored automatically and can be easily recalled. Automatic reporting capabilities reduce reporting time. Software for monitoring and reporting are available as integrated graphics packages with report generator options. Graphs can be presented on screen, plotted, sent to file or transferred to word processor programs. Calculated results are stored on hard disk and can be presented as tables, logs, or graphs.

Software configuration
Software for monitoring will work under MS-DOS 5.0 or higher and only when connected with the proper data acquisition card. Report software and TNOWAVE modules will run on: any IBM compatible computer (386 or higher), MS-DOS 5.0 or higher, Windows 3.1 in enhanced mode as DOS-program, Windows 95 as DOS-program. A VGA monitor, 4MB of available RAM and minimal 5MB hard drive are also required.

High Quality Signal Processing
Depending on the application, maximum sampling rates of 50 kHz or 300 kHz are available which allow full digital signal processing for maximum quality.

Transducers, connectors and cables
For the reliability and accuracy of measurements, high quality transducers, connectors and cables are

Available application on FPDS-6 KIT

	Application name	Use
SIT	Sonic IntegrityTesting	Detection of pile defects, pile length
PDA	Pile Driving Analysis	Analysis during impact pile driving
DLT	Dynamic Load Testing	Pile capacity determination
STN	STATNAMIC® Load Testing	Static load displacement behaviour
RADAR	Doppler Radar Hammer Monitoring	Hammer efficiency control
VDA	Vibratory Hammer Driving Analysis	Analysis during vibratory pile driving
VIBRA	Vibration Monitoring	Ground and structural vibrations
SWAY	Sway Monitoring	Monitoring of pile sway amplitudes
HAMMER	Hammer Monitoring	Impact velocity ram
THICK	Thickness Measurements	Concrete floors and walls
SPTC	SPT Controller	SPT energy control
SEISCONE	Seismic cone	Dynamic soil parameters
TNOWAVE	Stress Wave Program, TNOPDP, TNOVDP, TNODLT, TNOSIT, TNOSTN	Pile driving prediction, DLT and SIT signal matching and STN simulation

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essential. Specially designed transducers, cables, and junction boxes guarantee reliable functioning in harsh conditions with minimal mounting time.

Designed for the geotechnical and structural Engineer.

Units, input parameters, presentation of results, and graphics follow geotechnical and structural engineering standards. Automatic control of electronic functions by the computer ensures that the operator does not require a knowledge of internal electronics. The engineer can concentrate on monitoring and analysing results.

Why TNO products?

- TNO plays a major role in the developments of methods for dynamic pile testing.
- TNO is based in the Netherlands, a country with an extensive experience with piles and difficult ground conditions, onshore and offshore.
- TNO FPDS systems are multi functional units. TNO does not only develop systems for the market, but also for its own service needs. The best and most suitable systems are transferred to clients
- TNO is one of the world's largest independent research organisation with 4500 employees and was founded in 1936.
- TNO is recognised in many countries, the world over, for its experience and excellence in many fields of research and technology.
- All of TNO s expertise, experience, developments and know how for foundation testing are implemented in FPDS products and transferred to clients.
- TNO does not compete with FPDS clients in the pile testing market
- TNO has developed unique technologies with partners, like STATNAMIC and EMH hammer, which can not be supplied by competitors.
- The main goal of TNO is transfer of knowledge. Research results are shared with clients. This keeps clients up to date with the latest developments.
- Education, training and support of clients are very important to TNO when selling products.
- TNO works in joint projects with clients. In this way local expertise is combined with the technical knowledge and experience of TNO.
- TNO now organises FPDS user seminars in several geographical regions of the world. TNO also provides support services directly by fax, E-mail or FTP transfer.

Computers

The FPDS-6 KIT is best used with a Texas Micro HARDBODY™ PC. Other handheld or notebook PC's, equipped with a PCMCIA slort, can be used also. (contact TNO to check for suitability).

TEXAS MICRO HARDBODY™ PC

- 486 PC, 75 MHz
- 8MB DRAM memory,(16, 24, 32 MB options)
- 1MB flash memory
- a ruggedized IDE hard disk
- a 64-grey scale 640x480 VGA monochrome LCD
- a touch screen or tethered pen operation
- an external analogue VGA connector
- fully functional power management capability
- a rechargeable NiMH "smart" battery
- two PCMCIA PC Card slots
- a standard PS/2 keyboard connection
- AT connection possible via adapter cable
- two serial ports (one RS-232, one RS-232/422/485 selectable)
- an AT-compatible/bi directional parallel port
- support for an external floppy drive
- physical dimensions 240 x 190 x 55 mm
- weight 1,5 kg inclusive battery
- operating temperature range -10 °C to + 50 °C
- shock 20 g, 6 ms
- humidity, 0 to 95% RH, non-condensing
- display 122 x 88 mm viewing area, 640 x 480 resolution

Hardware information FPDS-6 KIT

Data acquisition

- PCMCIA - A/D converter card & signal conditioning:
  dual 14 bit 300 kHz A/D converters
  8 single ended analog input channels (2 x4)
  two constant current power source for piezoelectric accelerometers
- PCMCIA and external AD Converter components:
  AD Converter Board, 4 channels, 12 bits
  Maximum sample rate 50 kHz, on board MC68332 processor

Signal conditioning

- Frequency response depending on application
- Automatic gain control and auto zero levelling

Signal conditioner power supply

- Battery Pack: DC 12 V rechargeable
- Car Battery: DC 12 V, car battery via cigarette lighter or other external battery

Transducers and cables

Each application comes with dedicated transducers and cables. Information is supplied on the brochures of the application.

Transport case

Packed in rugged transport case

Specifications subject to change without notice.

Further information

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Foundation Pile Diagnostic System
FPDS-5

Pile Testing Equipment with Multiple Applications

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

Foundation Pile Diagnostic System FPDS-5
The FPDS-5 is part of a new generation of advanced pile testing equipment aimed specifically at the professional quality control market. Its modular, compact and cost-effective design is the result of more than 20 year research, development and experience in pile testing, onshore and offshore, all over the world.

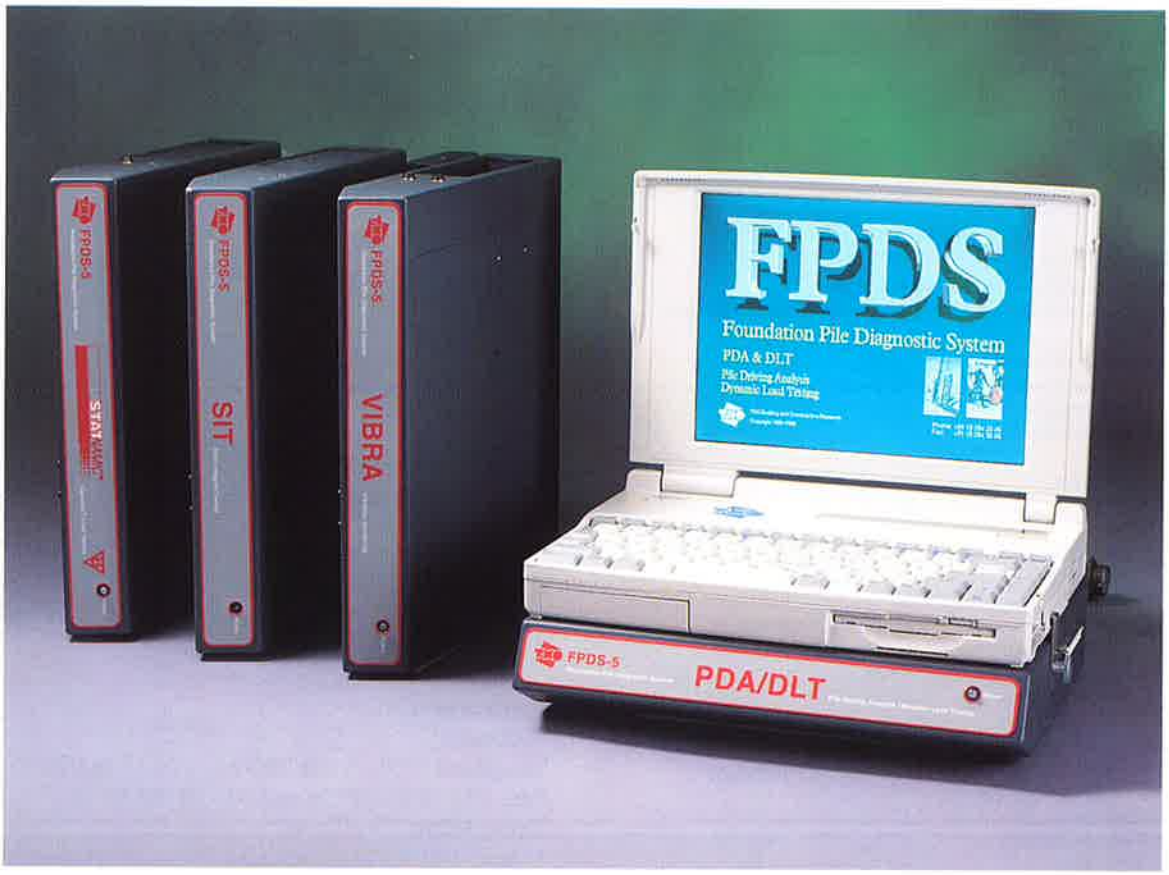
Powerful Data Acquisition System
The FPDS-5 is based on the combination of one powerful notebook computer combined with one or more compact robust signal conditioning units. For each application a signal conditioning unit is available. The client is free to make its own choice of notebook computer provided with a PCMCIA slot. The modular design allows an effective maintenance of the FPDS-5 system. In case of malfunctioning of the computer any other computer equipped with a proper PCMCIA slot can be used as a replacement.
For each application, the basic FPDS-5 system can be extended with an internal or an external signal conditioning unit and additional software, sensors, and cables. Each application comes with English manuals and training courses.

Easy to Use Operation
FPDS-5 software is menu driven and easy to use. Knowledge of electronics is not necessary - all electronic functions are controlled by the computer. Advice and warnings are generated by the system when required. Signals and other data are stored automatically and can be easily recalled. An integrated colour graphics package presents graphs on screen for filing or plotting. Calculation results are stored on hard disk and can be presented as tables, logs, or graphs. Automatic reporting capabilities reduce reporting time.

High Quality Signal Processing
A sampling rate of 50 kHz allows full digital signal processing for maximum quality.

Transducers, Connectors and Cables
For reliability and accuracy of measurements, high quality transducers, connectors and cables are essential. Specially designed transducers, cables, and junction boxes guarantee reliable functioning in harsh conditions with minimal mounting time.

Designed for the Geotechnical and Structural Engineer
Units, input parameters, presentation of results, and graphics follow geotechnical and structural engineering standards. Automatic control of electronic functions by the computer does not require knowledge of electronics. The engineer can put his full attention to monitoring and analyzing results.



Available application on FPDS-5

	Application name	Use
SIT	Sonic IntegrityTesting	Detection of pile defects, pile length
PDA	Pile Driving Analysis	Analysis during impact pile driving
DLT	Dynamic Load Testing	Pile capacity determination
STN	STATNAMIC® Load Testing	Static load displacement behaviour
RADAR	Doppler Radar Hammer Monitoring	Hammer efficiency control
VDA	Vibratory Hammer Driving Analysis	Analysis during vibratory pile driving
VIBRA	Vibration Monitoring	Ground and structural vibrations
SWAY	Sway Monitoring	Monitoring of pile sway amplitudes
HAMMER	Hammer Monitoring	Impact velocity ram
THICKNESS	Thickness Measurements	Concrete floors and walls
SPTC	SPT Controller	SPT energy control
SEISCONE	Seismic cone	Dynamic soil parameters
TNOWAVE	Stress Wave Program	Pile driving prediction, automatic signal matching, SIT, and STN simulation

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Hardware Information FPDS-5

Computers
The FPDS-5 system works with notebooks computers provided with PCMCIA slots which satisfy below mentioned specifications. The use of powerful notebooks (486DX or Pentium) are advised. Notebooks with black and white reflective LCD screens will perform best in bright sunlight. Colour screens can be used when sunligtht shelter is applied for outdoor use.

Specification PCMCIA

Host connector:	Standard PCMCIA type 2
FPDS-5 connector:	100 pin 3M Mini Delta
PCMCIA connector:	68 pin 3M Mini Delta (Connects the card to external cable)
PCMCIA host voltage:	+ 5 volt
PCMCIA host current:	100 mA maximum
PCMCIA adapter dimension:	
- width:	63.8 mm (AT adapter cable socket)
- length:	112 mm
- height:	16.2 mm (AT adapter cable socket)
Hot swap:	PCMCIA adapter and conditioner are not damaged by live connection and disconnection

AD Conversion
AD converter board, 4 channels, 12 bits
Maximum sample rate 50 kHz, on board MC68332 processor

Signal Conditioning
- Frequency response depending on application
- Automatic gain control
- Auto zero levelling

Power Supply

Battery pack:	DC 12 V rechargeable
Car battery:	DC 12 V, car battery via cigarette lighter or other external battery

Physical

Dimensions: (without connectors)	160 x 260 x 110 mm
Weight conditioner:	3.5 kg
Weight battery pack:	2.7 kg

Physical

Dimensions: (without connectors)	160 x 260 x 110 mm
Weight basic unit:	3.5 kg
Weight conditioner:	1.5 kg
Weight battery pack:	2.7 kg

Transducers and cables
Each application comes with dedicated transducers and cables. Information is supplied on the brochures of the application.

Transport Case
Packed in rugged transport case

Specifications subject to change without notice.

Further information

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Foundation Pile Diagnostic System
FPDS-α

Special Applications PDC, VIBRA, INCLI, HAMMER, STRAIN

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

Foundation Pile Diagnostic System FPDS-α
The FPDS-α system is part of a new generation of compact data acquisition and monitoring systems aimed specifically for simple and reliable operation on the building site and in the field. FPDS-α is the basic computer for special applications like the Pile Driving Controller, Vibration Monitoring, Inclination Monitoring, Hammer Monitoring and Multi Channel Strain Monitoring.

The FPDS- system consists of a powerful micro computer with data acquisition electronics and an internal battery. A single FPDS-α is equipped for one special application. Each special application comes with software, signal conditioning , sensors and cables. English written manuals and training courses are available.

Powerful Data Acquisition Micro Computer
Despite its small size (lunch box), the yellow FPDS- system is a powerful micro computer. For easy use in the field all functions can be reached by dedicated keys. Results are presented on a LCD screen with large characters. Data can be transferred to a PC by cable connection.

Easy to use
The FPDS-α software is easy to use. Knowledge of electronics is not necessary - all electronic functions are controlled by the micro computer. Warnings and messages are generated by the system when required. Measurement results are stored automatically and can be replayed, printed out or transferred to a PC.

Report Software
With this software input data for FPDS-α can be prepared at the office with a PC, to minimise input work on the building site. With the same software measured data is post processed and results are presented as tables, logs and graphs. Automatic report capabilities reduce the reporting time.

Transducers, Connectors and Cables
For reliability and accuracy of measurements, high quality transducers, connectors and cables are essential. Specially designed transducers, cables and junction boxes guarantee reliable functioning in harsh conditions with a minimal mounting time.

Available application on FPDS-α

	Application name	Use
PDC	Pile Driving Control	Automatic control of pile driving
VIBRA	Vibration Monitoring	Ground and structural vibrations
INCLI	Inclination Monitoring	Inclination of lead or hammer
HAMMER	Hammer Monitoring	Impact velocity ram
STRAIN	Strain measurements	Multi channel strain measurements

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Hardware Information FPDS-α

Micro Computer

Processor:	MC68332
Clock Speed:	16 MHz
RAM:	1 MB
Flash ROM:	256 Kbyte
Display:	LCD, 4 lines, 20 characters, 8 mm
Interfacing:	External Peripheral Connector (printer or high speed data link)

AD Conversion

AD Converter Board, 4 channels, 12 bits
Maximum sample rate 50 kHz, on board MC68332 processor

Power Supply

AC Power:	100-240 V AC, auto-sensing
Battery Pack:	DC 12 V, rechargeable battery;
Car Battery:	DC 12 V, car battery via cigarette lighter or other external battery

Environmental

Protection:	Rain proof
Temperature:	0 to 35 °C operating -20 to 65 °C storage
Humidity:	20 to 99% operating 5 to 99% storage
Shock:	5 g operating 80 g non-operating

Physical

Dimensions:	160 x 260 x 110 mm (without connectors)
Weight Basic Unit:	2.7 kg

Transducers and cables

Each application comes with dedicated transducers and cables. Information is supplied on the brochures of the application.

Batteries

Internal:	Rechargeable, Nic, 12 volt, 5Ah.
External type:	Rechargeable, lead acid, 12 volt, 12 Ah
Power Source:	Charge from 90-130 or 180-260 volt, 50/60 Hz power source

Keyboard

Build in keyboard:	dedicated keys alphanumerical keys

Transport Case

Packed in rugged transport case

Data Transfer

Data transfer between FPDS-α and PC via direct cable connection.

Specifications subject to change without notice.

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Foundation Pile Diagnostic System
FPDS-5 and FPDS-6 KIT

Summary of applications running on FPDS systems

TNO Building and Construction Research

Netherlands organization for applied scientific research

SIT,
Sonic Integrity Testing

A quick and inexpensive method to check the integrity of foundation piles. SIT detects pile defects, including cracks, soil inclusions, variations in pile diameter and pile length. It can be used for cast in situ piles and precast concrete piles. Analysis and reporting software are available. Quantitative information about pile defects is obtained with the SIT Automatic Signal Matching option of the stress wave program TNOWAVE (TNOSIT).

PDA,
Pile Driving Analysis

A powerful diagnostic tool to assist control and trouble shooting of the pile driving process. During driving, a complete installation record of the pile is obtained, including blow count, blow rate, compression stresses, tension stresses, transferred energy by the hammer and soil resistances. Immediately available driving records assist in optimising foundation installation through accurate selection of final driving depth. Pile Driving Analysis can be performed on steel, concrete and wooden piles.

DLT,
Dynamic Load Testing

A method to determine the load bearing capacity of foundation piles. A drop hammer or a conventional pile driving hammer is used to introduce an impact. Information is obtained about the contribution of shaft friction and the toe resistance to the load bearing capacity. The static load-displacement diagram can be calculated with the DLT Automatic Signal Matching option of the stress wave program TNOWAVE (TNODLT).

STATNAMIC®
Load Testing

A new approach to foundation testing.
A cylinder is bolted on the pile top. A reaction mass, attached to a piston is placed over the cylinder. Solid fuel propellant is ignited inside the cylinder, generating high pressure gases and accelerating the reaction mass.
An equal and opposite reaction, gently pushes the pile into the soil. The weight of reaction mass equals 5 % of the applied load. The applied pile top force and pile top displacement are measured directly using a load cell and laser beam system. STATNAMIC® data is acquired by FPDS and results are graphed as a load displacement diagram. The mobilised capacity and static load displacement behaviour can be presented immediately on site. STATNAMIC® is a joint development of Berminghammer Corporation (Canada) and TNO.

VDA,
Vibratory Hammer Pile Driving Analysis

A tool to monitor the installation of piles or sheet walls by vibratory hammers. During driving an installation record is obtained of stresses, accelerations, power supplied by the vibratory hammer, and vibration frequency.
Driving records are immediately available.

THICK
Thickness Measurements

Application for measuring the thickness of concrete floors and walls. A sensitive accelerometer is pressed onto the concrete surface and a pulse is introduced by an Electro Magnetic Hammer (EMH). Signals are analysed in the frequency domain and the measured thickness is presented on screen. Measurement data are stored on the hard disk and can be printed.
THICK is a joint development of Mitsubishi Electric Corporation (Japan) and TNO.

VIBRA,
Vibration Monitoring

Application to monitor and record vibrations caused by pile driving, traffic, machinery, explosions, or other vibration sources. Four vibration sensors, placed on the ground or connected to a structure can be monitored simultaneously. Continuous recording or event triggering can be selected. All measured signals are on hard disk and are processed real time. Typical values of the measured vibrations, according to the building code selected, are displayed on screen. A warning is given when any limits, set by the user are exceeded.

SPTC
Standard Penetration Test Control

The basic function of SPTC is the control of energy transfer during a standard penetration test. An instrumented rod with strain gages and accelerometers is placed between the trip hammer and driving rods. The transferred energy has a strong influence on the derived N-value. With SPTC the N-values obtained in the field can be normalised.

Stress wave program TNOWAVE,
The stress wave program TNOWAVE consists of 5 modules. TNOPDP for impact hammer pile driving prediction, TNOVDP for vibratory driving prediction, TNODLT to determine load displacement behaviour of a pile from DLT test results, TNOSIT to determine the dimensions and location of pile defects from SIT signals and TNOSTN to simulate a Statnamic load test on a foundation pile.

The measuring equipment
Foundation Pile Diagnostic Systems consist of a computer with hard disk, an A/D converter card, signal conditioning, electronics, sensor(s), cables and software for one or more applications. Reliability is proven by hundreds of FPDS systems used all over the world, and in our commitment to quality products and technical support. The use of FPDS systems and applications will improve your competitive power.

Software configuration
Application software consists of monitoring and report software. Software for monitoring works under MS-DOS 5.0 or higher and only when connected with the proper data acquisition card. Report software and TNOWAVE modules will run on: any IBM compatible computer (386 or higher), MS-DOS 5.0 or higher, Windows 3.1 in enhanced mode as DOS-program, Windows 95 as DOS-program. A VGA monitor, 4MB of available RAM and minimal 5MB hard drive are also required.

Interpretation, support and maintenance
The interpretation of test results requires a fundamental understanding of the applied technology. TNO conducts instruction courses, which are part of the system installation. TNO now organises FPDS user seminars in several geographical regions of the world. TNO also provides support services. Support can be provided by fax, E-mail or FTP.

FPDS applications are presently used and serviced in over 36 countries. We have agents in most regions of the world, who speak your language and understand your special needs and local conditions.
Maintenance contracts are available, on an annual basis, and include calibration of sensors, minor repairs, cleaning and free loan systems

Other applications
More applications, like Radar Hammer Monitoring and Pile Sway Monitoring, are available.
For a full list of software applications and particular advantages of each application system please consult the appropriate hardware documentation. TNO can provide additional assistance in selecting the best hardware platform for your needs.

Specification subject to change without notice.

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VIBRA Measuring system for Vibrations
Foundation Pile Diagnostic System FPDS-α

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

Versatile measuring system
Easy registration of vibration is in great demand. VIBRA-α makes it easy to measure and analyse vibrations. Whether they're traffic induced, due to pile driving or caused by explosions, the system displays the vibrations and stores them in its memory.

Fast installation
Installation of the VIBRA-α takes practically no time at all, and can be done immediately. With the aid of simple keys, either the peak amplitude values (top values) of the vibration velocity or the vibration acceleration can be displayed. It is also possible to have the effective amplitude values, or KB value, displayed constantly. The dominant vibration frequency is displayed as a standard feature.

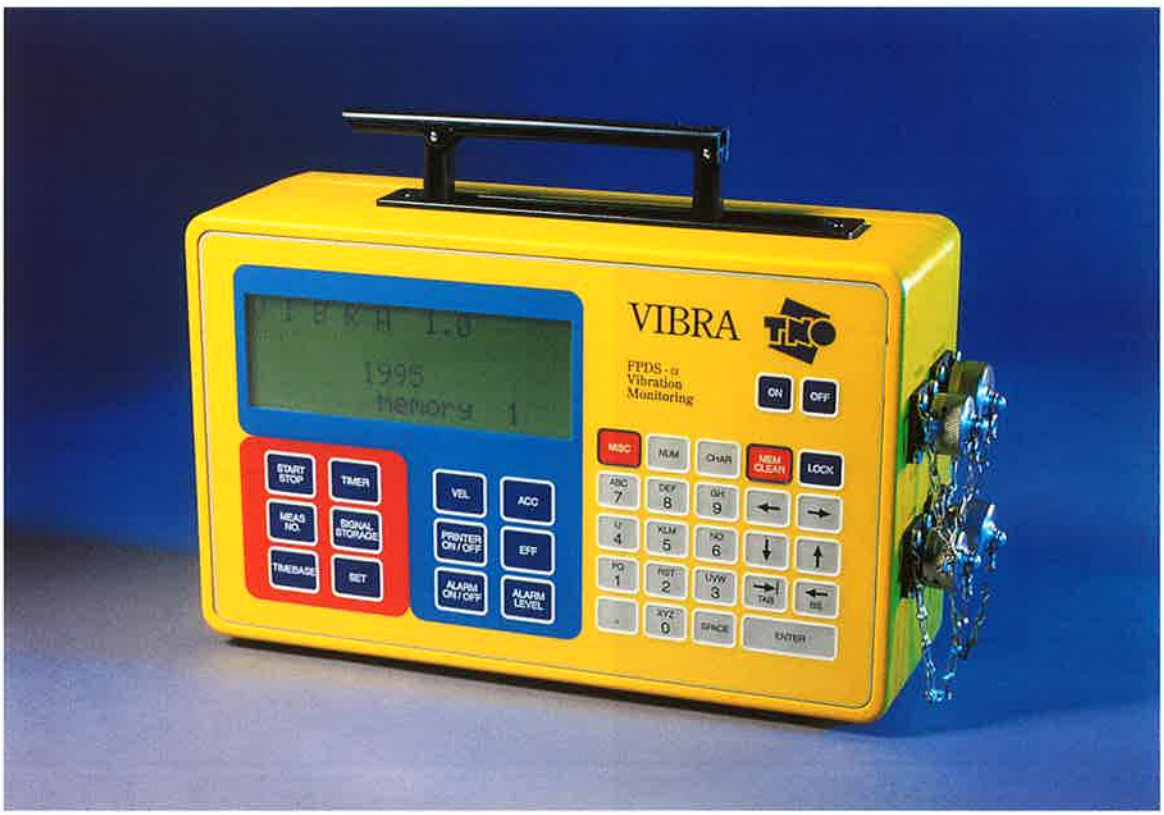
Storage of measuring signals
All measured values are stored in the memory of the VIBRA-α. The measuring signal can also be stored in the memory. VIBRA-α offers the user the option of storing the vibration signals associated with the peak amplitudes. These measuring signals can be transferred to a PC for analysis on a time or frequency presentation of acceleration, velocity or frequency spectra.

VIBRA-α works on either internal batteries or external power supply (12V). Sensors working in three mutually perpendicular directions are a standard feature of the VIBRA-α. A maximum of four sensors can be attached. Optionally, a microphone can be attached, in which case the noise level in dB(A) will be displayed.

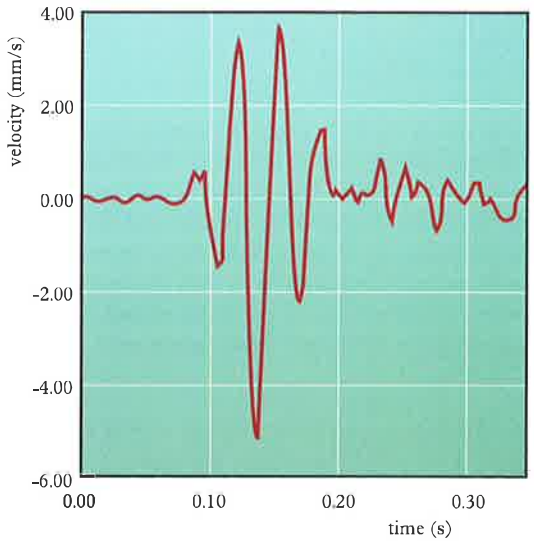
Multiple uses
Direct display: dominant frequency and maximum value of vibration:
- acceleration;
- velocity;
- KB value (DIN 4150).

Alarm levels for both vibration acceleration and vibration velocity can be adjusted. These alarm levels can be adjusted manually, but the standards and directives for vibration damage and nuisance (BS 6472, ISO 2631, DIN 4150) can also be used. Any breach of the alarm levels will be displayed. It is also possible to activate external alarms such as loudspeakers, sirens and light signals with VIBRA-α.

All adjustments can be carried out with the simple-to-use VIBRA-α keys. No external keyboard or PC connections are needed.



Many presentation options
All results of the measurements (peak amplitudes of vibration acceleration and vibration velocity) can be printed out on an external printer during the measurement. The results can also be printed from the VIBRA-α when the measurement has been completed.



Storage of measurement results
The maximum values are stored in VIBRA-α's internal memory. The vibration signals can also be stored. The vibration signals relating to the highest peak amplitudes within a certain period (one hour) can be stored. It is possible to adjust the number of vibration signals per hour and the length of these signals in seconds.

The internal memory is large enough to store peak amplitude values of vibration signals for about one week of measurement. If the vibration signals are not saved, the memory has sufficient capacity for over a month of continuous measuring.

Reliable sensors
The sensors supplied with VIBRA-α are robust and work in a range from 1 to 100 Hz. The sensors have fasteners so they can be mounted on a wall, for instance.

Extra functions
- lock function so that unauthorized persons can not operate the VIBRA-α;
- timer function for starting and stopping measurements;
- a PC program is included with the VIBRA-α for closer analysis of the measured data and to produce graphical displays (time and spectral) and tables.

Specifications
For general information see "FPDS Special Applications"
Maximum: 4 sensors
- Standard: X, Y, Z 3-D sensors
- Optional: Combined X, Z 2-D sensor
  Single Z or X 1-D sensor

Sensibility:
- 5 - 100 Hz
- 0.1 - 30 mm/s

Rechargeable Internal Battery sufficient for 8 hours continuous measurement.

External connectors for:
- printer
- alarm

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Sonic Integrity Testing
SIT

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

The purpose of Sonic Integrity Testing
Sonic Integrity Testing is a quick and cheap method to check the continuity of installed foundation piles. The method will detect pile defects like cracks, soil incursions and diameter changes. It can be used for precast concrete piles and for cast-in-place piles. The method is also called low-strain testing.

How does it work?
The pile head is struck with a hand-held hammer, which sends compressions wave down the shaft of the pile. Pile discontinuities and the pile end reflects an upward travelling stress wave. The movement of the pile head, caused by the hammer impact stress wave and their reflections, is sensed by a sensitive accelerometer. This accelerometer is easily attached to the pile top using a viscous material. The signal is converted into a velocity measurement and presented on screen as a function of time and can be stored. The velocity graph of an undamaged pile normally consists of a very large peak at the time of impact. A smaller peak, corresponding to the pile toe, can often be distinguisted. Soil changes may often cause intermediate reflections. On the first figure a normal screen layout is shown with three measurements for a concrete pile with a length of 25 m.

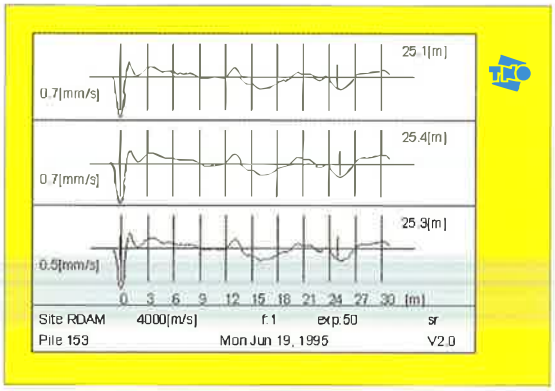
A powerful tool for interpretation is the TNOSIT stress wave module of TNOWAVE. It allows to build a model of the pile and the soil, and to simulate Sonic Integrity Testing. The actual signal and the simulated signal are compared and the model parameters adjusted automatically, until a good match is obtained, see second figure. Proper use of this tool will result in a more accurate determination of the severity of cross-sectional variations.

Advantages of Sonic Integrity Testing?
- Defects are discovered at an early stage.
- The approximate pile length can be determined.
- Any accessible pile can be tested by single operator.
- Quick and economic: 100-300 piles a day.
- Minimal interference with site activity.

Limitations of Sonic Integrity Testing?
- Minor cross sectional deficiencies (< 5%) can not be detected.
- A toe reflection is not always obtained. Shaft friction reduces the energy of the stress wave. In very stiff clays penetration might be limited to 7 m. In very soft soils, pile lengths of 80 m have been detected.
- The method is less suitable for segmented piles, when there is a loose connection between the segments. Piles having a large pile cap or other large discontinuities generally are not suitable for testing.

Does Sonic Integrity Testing give information about load bearing capacity?
No information is obtained regarding load bearing capacity. For the assessment of load bearing capacity other techniques, called Dynamic Load Testing (DLT) and Statnamic® (STN) may be used.

Is Sonic Integrity Testing backed by enough experience?
SIT was developed by TNO in the late 1960's. Experience has been gained on millions of piles by



SIT measurement result.

TNO and our clients. Our SIT systems are presently used and serviced in over 36 countries. We have agents in most regions of the world, who speak your language and understand your special needs and local conditions. SIT is recognised as the industry standard for low-strain testing. Literature describing the results and subsequent inspections is available from TNO.

Pile preparation and other conditions

- The pile head must be clean, accessible, sound and free from standing water. However a smooth surface is not required
- The concrete should be, in general, not less than one week old at the time of testing.
- A drawing should be provided showing the pile reference numbers and locations.
- It is necessary, for the setting of the display scales and for the understanding of the characteristic response of the piles, to know both the approximate pile length and the soil conditions through which it penetrates.

Imstrumented hammer

Defects which are located close to the pile top (first 1-2 meters) are difficult to determine as the reflection of this defect arrives during the hammer blow. The result is a superposition of the two signals, which may confuse the interpreter. To overcome this problem, an instrumented hammer (optional) can be connected, which measures the force impulse at impact.

Frequency domain

Although time domain analysis yields all necessary information and is strongly supported by TNO, a frequency domain application (optional) has been added to the SIT package. The force from instrumented hammer and the velocity signal are used to calculate the mechanical admittance as function of the frequency. From this graph the pile length and impedance are determined.

The equipment

SIT is supported by FPDS-4, FPDS-5 and FPDS-6 KIT.

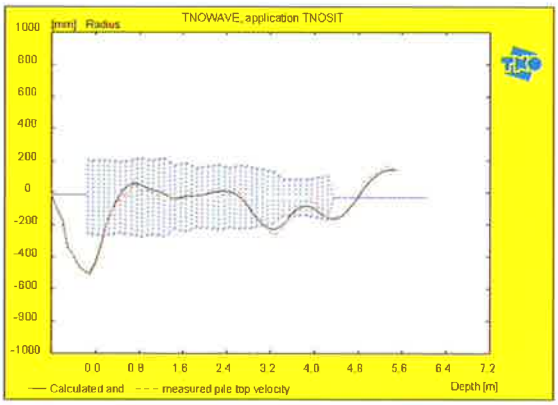
FPDS systems consist of a computer with hard disk, A/D converter card, signal processing electronics, cables, preamplifiers and a hammer. Software is available for monitoring and reporting. Low-noise amplification and signal processing techniques are utilised to preserve the information in the acceleration signal. The system is operational within minutes and very easy to learn and operate. Reliability is proven by hundreds of FPDS systems used all over the world, and in our commitment to quality products and technical support.

Interpretation, support and maintenance

The interpretation of test results requires a fundamental understanding of the applied technology. TNO conducts instruction courses, which are part of the system installation. TNO now organises FPDS user seminars in several geographical regions of the world. TNO also provides support services. Signals causing interpretation difficulties may be sent to TNO by fax, E-mail or FTP, where experts will give their interpretation. Maintenance contracts are available, on an annual basis, which include; calibration of sensors, minor repairs, cleaning and free loan systems.

Other applications

For a full list of software applications and particular advantages of each application system please consult the appropriate hardware documentation. TNO can provide additional assistance in selecting the best hardware platform for your needs.



Pile shape derived with TNOSIT.

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Pile Driving Analysis
PDA

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The purpose of Pile Driving Analysis
Pile Driving Analysis (PDA) is a powerful tool to control the pile driving process. During driving, the performance of the hammer, the condition of the cushion, the behaviour of the pile and the driving resistance of the soil can be analysed. Thus the following can be optimised:
- control of the pile driving process;
- trouble shooting;
- acquiring information about ultimate soil resistances;
- high strain integrity testing;
- quality assurance;
- pile driving optimisation.

Pile Driving Analysis (PDA) is one of the 14 applications supported on Foundation Pile Diagnostic Systems (FPDS).

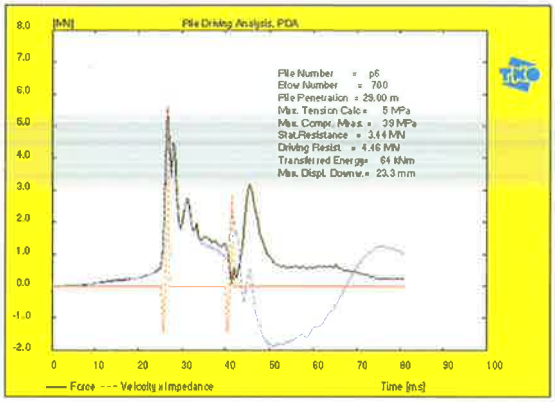
The extra knowledge which is obtained by performing Pile Driving Analysis can pay for itself many times over. The risk of damage to the pile or the hammer is reduced. The risk of damage to the superstructure caused by failure of the foundation is reduced. The final depth of driving can be optimised, which may result in a shorter pile length. For future projects, prediction of pile driving and selection of the correct hammer is facilitated. A quality record of each pile can be supplied to the clients and authorities.

How does it work?
Two sensors are quickly connected to the pile in the region of the pile head. The sensors have a combined function; each of them senses strain and acceleration. On precast concrete piles the sensors are connected to the pile with anchor bolts. On steel piles the sensors are bolted to the pile using threaded holes or mounting blocks which are welded. Special sensors for underwater use are available. All sensors may be recovered after driving. The signals from the sensors are processed by the program in the FPDS computer, and stored in digital form on the internal hard disk. Digital storage of signals preserves the signal quality. The stored signals can be retrieved and processed by the post-processing option of the software.

A pile test can be set up in less than a quarter of an hour. After the sensors have been connected, the menu driven program guides the operator during adjustment of the controls. Pile driving may start immediately. During driving, data is stored automatically on hard disk for back-analysis and generation of field reports. The system is operational within minutes and very easy to learn and operate. Reliability is proven by hundreds of FPDS systems used all over the world, and in our commitment to quality products and technical support.

What kind of information is obtained?
The signals and other information can be presented immediately on screen. A selection of the available graphs, all presented as a function of time, and scaled in engineering units, include:
- the measured signals;
- transferred energy;
- acceleration, force, velocity and displacement at the sensor location;
- force and velocity x impedance;
- downward travelling waves;
- upward travelling waves;
- driving resistance.

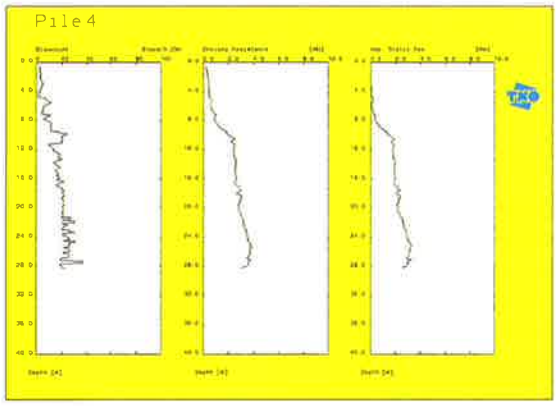
During driving, the following information is available for each hammer blow: blow number, blow count, blow rate, maximum compression and tension stress in the pile, transferred energy, driving resistance, shaft friction and toe resistance, bending moment, maximum acceleration, the pile structural integrity, extent and location of damage. Results are presented in either SI or English units. A report generator program allows the presentation of a field report immediately after driving. The system gives warnings and other 'expert advice'.



PDA signals.

Does Pile Driving Analysis provide information about static load bearing capacity?

Yes, but not during actual pile driving. Adequate time should be allowed for soil set-up and stabilisation to take place, before an instrumented redrive is attempted. For cast-in-place piles the concrete strength should be high enough to resist the impact loading. More information about this test method may be found in the separate leaflet on Dynamic Load Testing (DLT). Soil resistance during pile driving can be calculated with the TNO method, the Case method or the Impedance method.

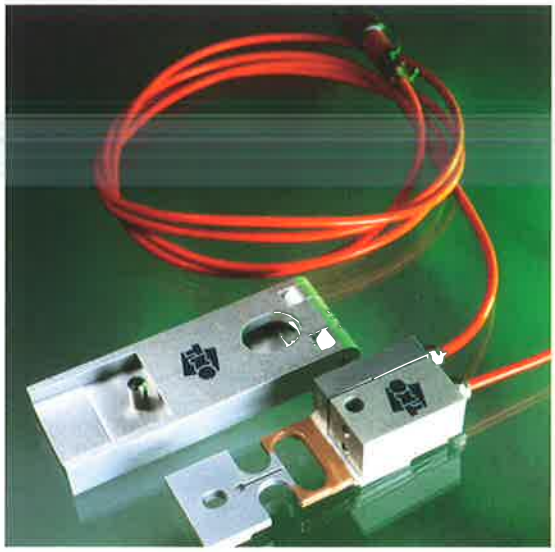


PDA monitoring results.

The measuring equipment

PDA is supported by FPDS-4, FPDS-5 and FPDS-6 KIT.

Foundation Pile Diagnostic Systems are tools for the civil engineer. They have been designed to be used in the building site environment. It consists of a FPDS system with hard disk, signal processing electronics, a signal conditioning subsystem, two combined sensors for strain and acceleration and cables.
The software consists of the PDA/DLT software for monitoring and reporting. Knowledge of electronics is not required.



Combined strain- acceleration transducer + mounting rig.

Cable reel, junction box and PDA transducer.

Other applications

For a full list of software applications and particular advantages of each application system please consult the appropriate hardware documentation. TNO can provide additional assistance in selecting the best hardware platform for your needs.

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Dynamic Load Testing
DLT

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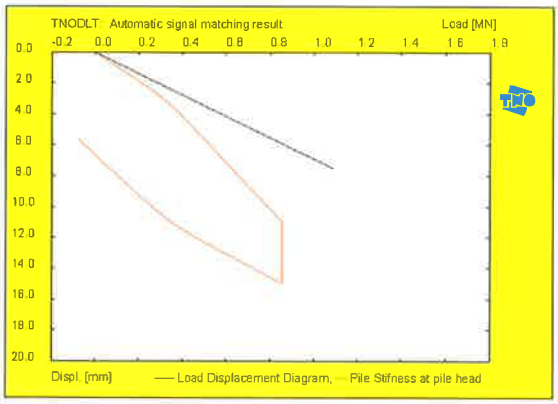
The purpose of Dynamic Load testing
Dynamic Load Testing (DLT) is a method to quickly evaluate the bearing capacity of a pile under a load of the same order as the design load. It can be used for prefabricated piles, cast-in-place concrete piles, steel piles and wooden piles. The DLT is considerably faster than static tests, at a fraction of the cost.

How does it work?
Two identical sensors are quickly connected to the side of the pile, opposite to each other, near the pile head. An impact hammer or a heavy, guided block is dropped onto the specially prepared pile head. The generated compression wave travels down the pile and reflects from the pile toe upward. The waves which are picked up by the sensors are processed and automatically stored in the field by the FPDS computer. The data can be easily retrieved for further review, graphical presentations or reporting.

Does Dynamic Load Testing provide information about static load bearing capacity?
Yes, but in order to assess static performance by this method it is necessary to establish the dynamic pile resistance and the relationship between static and dynamic pile performance, when no experience is available. Where adequate load experience exists on simular piles, it is possible to obtain satisfactory results without the above mentioned comparative static test. In this case the following procedure is normally used:
After a Dynamic Load Test, an analysis is carried out using the TNODLT stress wave module (see separate leaflet) on your PC or on a FPDS system. Pile and soil data are modelled and a calculation is carried out using the wave equation. The soil models describe the behaviour in terms of displacement, velocity and acceleration functions, using empirical parameters which depend on the known soil properties.
Using automatic iterative methods in which the results of each TNODLT analysis are compared to



Predicted static load displacement diagram.

the actual measured pile behaviour, appropriate dynamic parameters are refined and the shaft and toe resistance established. This procedure can be performed automatically and is called "Automatic Signal Matching".
DLT is most suitable for driven piles. For cast-in-place piles the energy can be too limited to mobilise full capacity or stresses can become too high, thus damage the pile. In such cases STATNAMIC™ is more appropriate.

Can Dynamic Load Testing be used to compare the bearing capacities?
When the results of Sonic Integrity Testing on a pile casts doubt upon the competence of a pile to carry its design load, this pile can be subjected to dynamic load testing. By comparing the results with those from another pile which is considered to be reliable, an estimation can be made of the capacity. To do this both the settlement behaviour and the dynamic resistances are examined. Piles which behave similarely, are generally considered to have equal capacities.

Is dynamic load testing backed by enough experience?
Dynamic Load Testing (DLT) is backed by 20 years of experience. Tests have been carried out by TNO and clients all over the world, onshore and offshore.

The first DLT system was developed in 1974. It is presently used and serviced in over 36 countries. DLT is recognised as an industry standard for high strain dynamic testing.

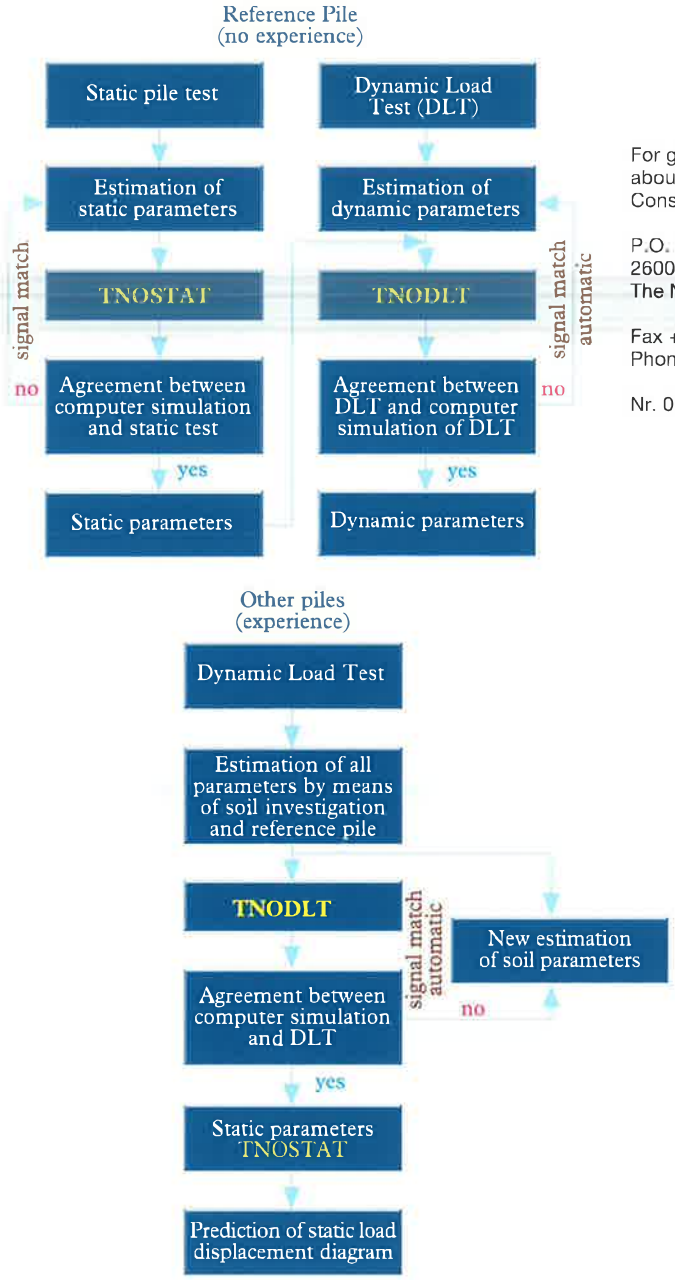
Pile preparation
Two combined sensors for strain and acceleration are connected to the side of the pile, opposite to each other, using anchor bolts or mounting blocks with threaded holes. Precast concrete piles and steel piles, when driven by the pile driving hammer, need no further preparation. Cast-in-place piles need more preparation. The pile top is flattened and a heavy steel plate is fixed to the pile top with anchor bolts. The gap is filled with a quick-hardening resin cement. A guide bar is placed vertically in the center of the steel plate. This bar guides the drop weight. Generally, Dynamic Load Testing should not be done during or immediately after driving. Adequate time should be allowed for soil set-up and stabilisation to take place.

The measuring equipment
The Foundation Pile Diagnostic System, (option PDA/DLT) has been specially designed for this testing method. It consists of a FPDS system with hard disk, signal processing electronics, a signal conditioning subsystem, two combined sensors for strain and acceleration and cables. The software consists of the PDA/DLT software for monitoring and reporting and the TNODLT module for automatic signal matching. The system is operational within minutes and very easy to learn and operate. Reliability is proven by hundreds of FPDS systems used all over the world, and in our commitment to quality products and technical support.

Dynamic Load Testing (DLT) is one of the 14 options supported on Foundation Pile Diagnostic Systems (FPDS). Three of these systems will support DLT; FPDS-4, FPDS-5 and FPDS-6 KIT.

Interpretation, support and maintenance
The interpretation of test results requires a fundamental understanding of the applied technology. TNO conducts instruction courses, which are part of the system installation. TNO now organises FPDS user seminars in several geographical regions of the world. TNO also provides support services. Support can be provided by fax, E-mail or FTP.
Maintenance contracts are available, on an annual basis, which include; calibration of sensors, minor repairs, cleaning and free loan systems.
TNO has agents in most regions of the world, who speak your language and understand your special needs and local conditions.

Other applications
For a full list of software applications and



DLT analysis diagram.

particular advantages of each application system please consult the appropriate hardware documentation. TNO can provide additional assistance in selecting the best hardware platform for your needs.

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Dynamic Load Testing Signal Matching - Automatic
TNODLT

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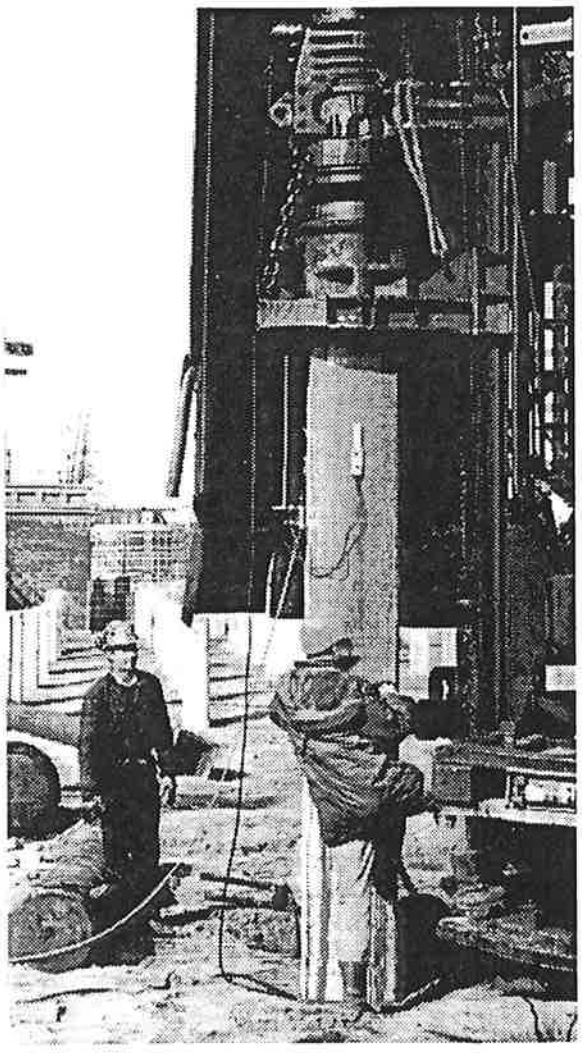
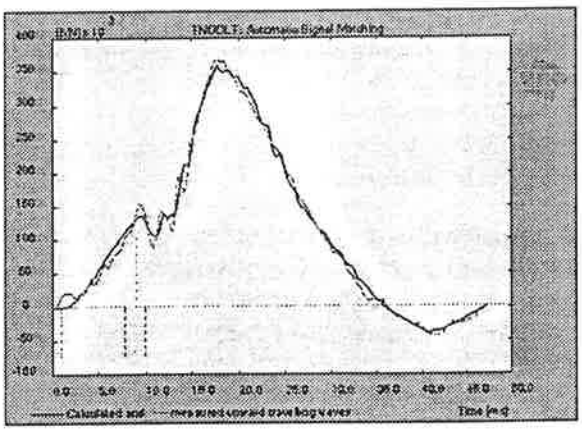
The purpose of Automatic Signal Matching with TNODLT
The TNODLT program is part of the TNOWAVE package. TNODLT simulates the dynamic load test (DLT) obtained with the signals of an FPDS system with the option PDA/DLT. Measured forces and velocities are used as boundary conditions at the pile top. With the results of TNODLT the piling engineer can calculate static load displacement behaviour.

How does it work?
The pile and soil are modelled. In an automatic iterative way measured and calculated signals are matched. When a good match is obtained it is assumed that the computer soil model represents the real behaviour. From the computer model, the static load displacement behaviour of pile and soil is calculated.

The user interface
A menu oriented user friendly environment has been created around TNODLT. Menus guide the user through the program and all dimensions and parameters are expressed in engineering units (SI or English). Sonic Integrity Testing (SIT), Pile Driving Analysis (PDA) and Dynamic Load Testing (DLT) options all store their signals in a uniform file format which can be read by TNOWAVE modules. Therefore, signals obtained with any of these programs may be processed using any TNOWAVE module. TNODLT itself has storage facilities for input data and calculation results. On screen, results are presented in the form of graphs or text. All results can be plotted.





How to determine static load bearing capacity?
A comparison is made between calculated signals from TNODLT, and actual signals obtained from Dynamic Load Testing or Pile Driving Monitoring. Instead of direct calculation of the pile shapes and soil models, the program performs the Signal Matching as an engineer would do. The program has a search strategy to find the best fit between calculated and measured signals. The supervision of an experienced engineer, with sufficient experience in performing matches manually, geotechnical knowledge and practical experience in foundation engineering is and remains required. Automatic Signal Matching does not replace the engineer; it will support him to perform the matching easily and, of special mention, faster.

Which soil models are available?
The Randolph-Deeks, Smith and TNO soil models are available for the shaft friction and the toe resistance, either linearly or non-linearly dependent on displacement, velocity and acceleration. The user should estimate reasonable limits for soil parameters. These can be compared with the result of the Automatic Signal Match. For example, is a high yield stress possible when the soil investigation shows a soft layer ?

What does the output look like?
Three locations may be defined along the pile, for which graphical output can be obtained. A fast selection option of possible output, each as a function of time, can include:
- forces, upward and downward travelling waves for measured and calculated signals;
- acceleration, velocity, displacement for measured and calculated signals;

energy;
shaft friction and toe resistance.
Similar output can also be plotted as a function of depth. Presentation of these graphics while the program is running visualises the propagation of stress waves in the pile. A selection of the text output is:
all input data;
maximum stresses in pile;
maximum acceleration, velocity and displacement;
maximum energy;
ultimate soil resistances;
ultimate shaft friction per layer;
ultimate toe resistance.

What algorithm is TNOWAVE based on?
The TNOWAVE stress wave propagation algorithm is based on the Method of Characteristics. This method has proven to be accurate and stable. The method was invented in the Netherlands in the early 70's by the company HBG and was adopted by TNO at that time and further developed.

Are there other stress wave simulation applications?
This stress wave program TNOWAVE consists of 5 modules. TNOPDP for impact hammer pile driving prediction, TNOVDP for vibratory hammer driving prediction, TNODLT to determined load displacement behaviour of a pile from DLT test results, TNOSIT to determine the dimensions and location of pile defects from SIT signals and TNOSTN to simulate a Statnamic load test on a foundation pile.

Configuration
The program will run on any IBM compatible 80386 computer or faster, equipped with a floating point coprocessor, MS-DOS 5.0 (or Windows 3.1 in enhanced mode), VGA monitor, 4 MB of available RAM and minimal 5 MB hard drive.

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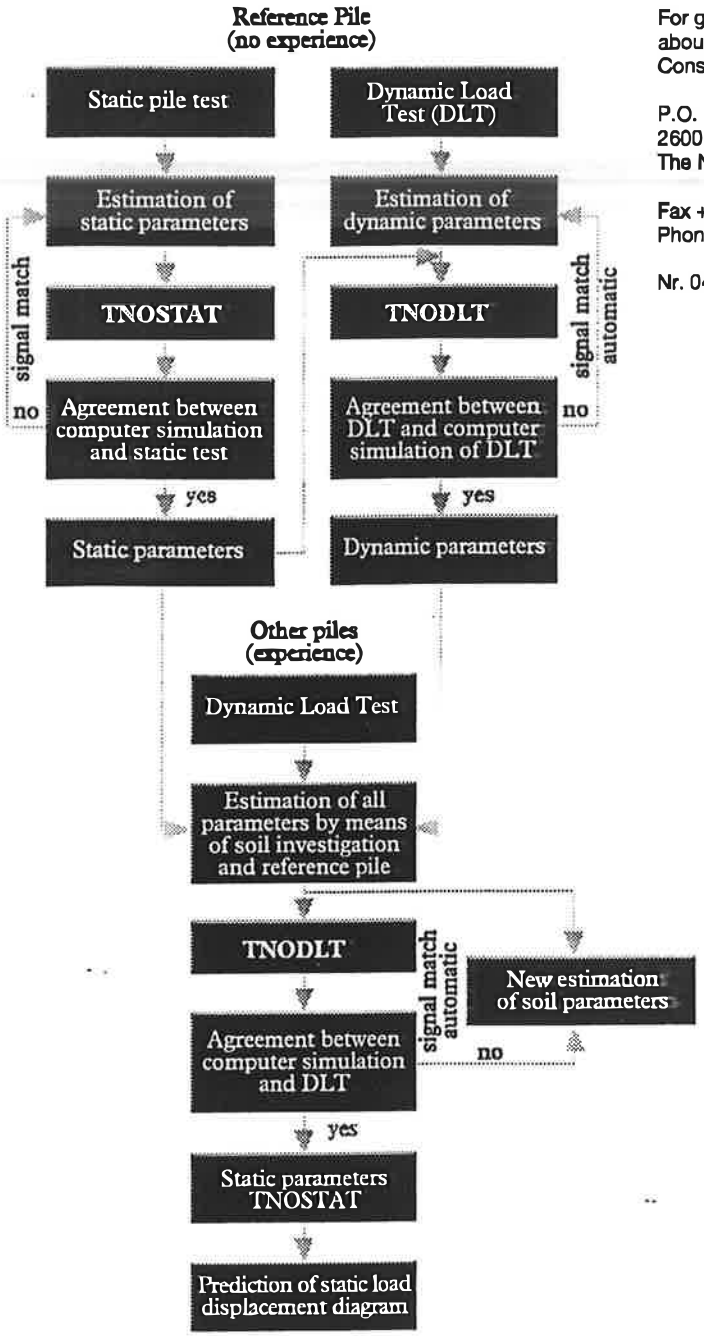

DLT analysis diagram.

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Prediction of Pile Driving for Impact Hammers
TNOPDP

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The purpose of TNOPDP

The TNOPDP program is part of the TNOWAVE package. TNOPDP simulates the pile driving process for many combinations of pile driving hammers, cushions, pile types and soil conditions.

With the results of TNOPDP the piling engineer can:

- predict driveability;
- optimise the selection of the impact hammer;
- select the maximum energy level without damaging the pile;
- increase the efficiency of the pile driving set-up: hammer, impact block, anvil, various cushions, etc.;
- when the compression or tensile stress exceeds the pile material strength the pile will be damaged. This can especially occur for concrete piles. With TNOPDP damage can be predicted and precautions can be taken;
- optimise the pile design. How many reinforcement bars are optimal, what is the optimum prestress level, etc? What will be the influence of different wall thickness by open steel pipes?;
- optimise the hammer for pile driving;
- optimise the dimensions of hammers, e.g. manufacturers of diesel, steam, impact and hydraulic hammers, can optimise their products;

- optimise follower design. The service life of the follower is mainly governed by fatigue.

The user interface

A menu oriented user friendly environment has been created around the TNOPDP. Menus guide the user through the program and all dimensions and parameters are expressed in engineering units (SI or English).

TNOPDP allows the modelling of:

- all types of hammers, anvils and cushions;
- tubular steel piles, open ended or closed;
- sheet piles, H-piles;
- concrete piles, circular, square or any other cross section:
- shaft friction and toe resistance.

SPT, CPT or laboratory soil testing results can be directly used as input data.

On the screen, the results are presented in the form of graphs or text. All results can be plotted.

Which hammer models are available?

The type of impact hammers included in TNOPDP are: hydraulic, steam, diesel hammers and other types of impact rams. The routine for combustion of the diesel in a diesel hammer is based on the physics of combustion. This results in an accurate description of the performance of the hammer. Users can easily edit hammer details as required.

Which soil models are available?

The Randolph-Deeks, Smith and TNO soil models are available for the shaft friction and the toe resistance, either linearly or non-linearly dependent on displacement, velocity and acceleration.

What does the output look like?

TNOPDP is equipped with extensive graphics and reporting options. Three levels may be defined along the pile, from which graphical output may be obtained. A selection of possible output are:

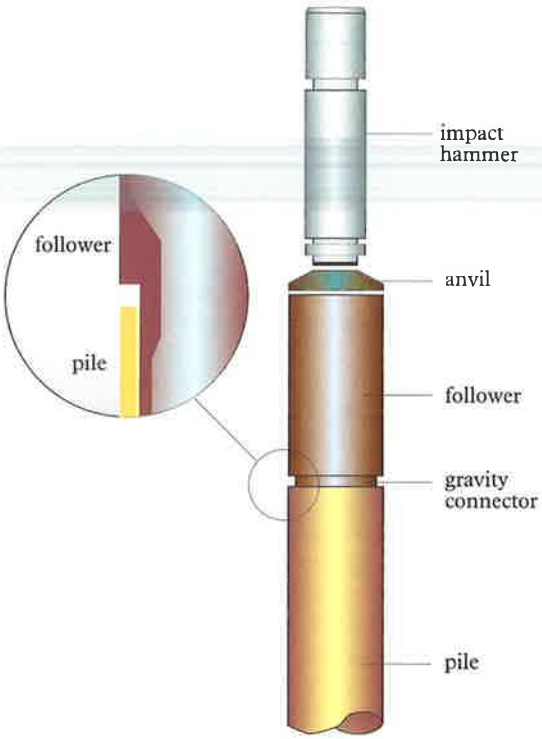
- time signals;
  - impact force, upward and downward travelling waves;
  - acceleration, velocity, displacement;
  - soil resistance;
  - transferred energy;
- driving logs;
  - blow count;
  - blow rate;
  - set per blow;
  - maximum compression and tensile stresses;
  - maximum energy: both theoretical, impact and transferred in the pile;
  - maximum acceleration, velocity and displacement;
  - soil resistances during driving and static resistance;
  - toe resistance and shaft friction per layer.

What algorithm is TNOWAVE based on?
The TNOWAVE stress wave propagation algorithm is based on the method of characteristics. This method has proven to be accurate and stable. The method was invented in the Netherlands in the early 70's by the company HBG and was adopted by TNO at that time and further developed..

Does TNOPDP have hammer libraries ?
Like most TNOWAVE modules TNOPDP has an extensive hammer library. The hammer library is regularly updated. TNOPDP also allows user defined vibratory hammers.

Are there other stress wave simulation applications ?
The stress wave program TNOWAVE consists of 5 modules. TNOPDP for impact hammer pile driving prediction, TNOVDP for vibratory hammer driving prediction, TNODLT to determine load displace-ment behaviour of a pile from DLT test results, TNOSIT to determine the dimensions and location of pile defects from SIT signals and TNOSTN to simulate a Statnamic load test on a foundation pile.

Configuration
The program will run on any IBM compatible 80386 computer or faster, equipped with a floating point coprocessor, MS-DOS 5.0 (or Windows 3.1 in enhanced mode), VGA monitor, 4 MB of available RAM and minimal 5 MB hard drive.



Follower modelling.

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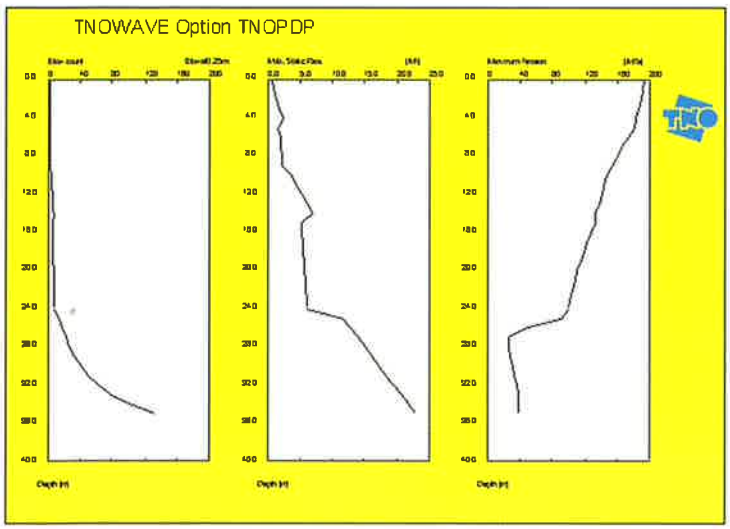

Pile driving prediction results

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Prediction of Pile Driving for Vibratory Hammers
TNOVDP

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The purpose of TNOVDP
The TNOVDP module is part of the TNOWAVE package. TNOVPD simulates the installation process for many combinations of vibratory hammers, pile types and soil conditions.

With the results of TNOVDP the piling engineer can:
- predict driveability;
- optimise the selection of the vibratory hammer;
- select the optimum frequency and driving force;
- avoid early refusal of the driving or extraction process;
- prevent damage to the pile. When the compression or tensile stress exceeds the pile material strength the pile will be damaged. With TNOVDP damage can be predicted and precautions can be taken.

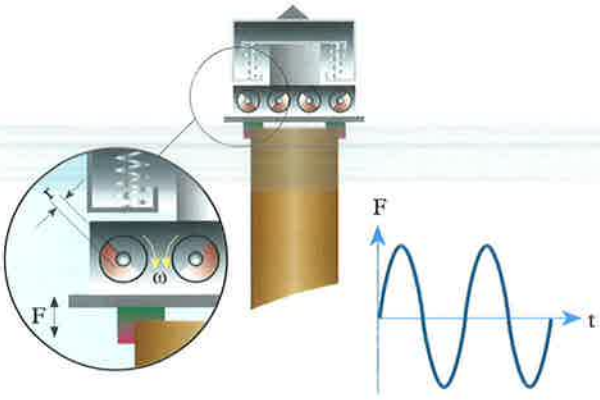
The user interface
A menu oriented user friendly environment has been created around the TNOVDP. Menus guide the user through the program and all dimensions and parameters are expressed in engineering units (SI or English).

TNOVDP allows the modelling of:
- all types of vibratory hammers;
- tubular steel piles, open ended or closed; sheet piles, H-piles;
- shaft friction and toe resistance.
SPT, CPT or laboratory soil testing results can be directly used as input data.

On the screen, the results are presented in the form of graphs or text. All results can be plotted.

Which soil models are available?
The Randolph-Deeks, Smith and TNO soil models are available for modelling the shaft friction and the toe resistance, either linearly or non-linearly displacement, velocity dependent and acceleration dependent. Degradation of the soil resistance during driving can be taken into account.

What does the output look like?
TNOVDP is equipped with extensive graphics and reporting options. Three levels may be defined along the pile, from which graphical output may be obtained.



Vibratory hammer modelling.

A selection of possible output are:
- time signals;
  - oscillating forces, upward and downward travelling waves;
  - acceleration, velocity, displacement;
  - soil resistances;
- driving logs;
  - time count;
  - penetration rate;
  - maximum compression and tensile stresses;
  - power supplied;
  - maximum acceleration, velocity and displacement;
  - soil resistances during driving and static resistance;
  - toe resistance and shaft friction per layer.

Are there other stress wave applications ?
The stress wave program TNOWAVE consists of 5 modules. TNOPDP for impact hammer pile driving prediction, TNOVDP for vibratory hammer driving prediction, TNODLT to determine load displacement behaviour of a pile from DLT test results, TNOSIT to determine the dimensions and location of pile defects from SIT signals and TNOSTN to simulate a Statnamic load test on a foundation pile.

What algorithm is TNOWAVE based on?
The TNOWAVE stress wave propagation algorithm is based on the method of characteristics. This method has proven to be accurate and stable.
The method was invented in the Netherlands in the early 70's by the company HBG and was adopted by TNO at that time and further developed.

Does TNOVDP have hammer libraries ?
Like most TNOWAVE modules TNOVDP has an extensive hammer library. The hammer library is regularly updated. TNOVDP also allows user defined vibratory hammers.

Configuration
Application software consists of monitoring and report software. TNOWAVE modules will run on: any IBM compatible computer (386 or higher), MS-DOS 5.0 or higher, Windows 3.1 in enhanced mode as DOS-program, Windows 95 as DOS-program. A VGA monitor, 4MB of available RAM and minimal 5MB hard drive are also required.

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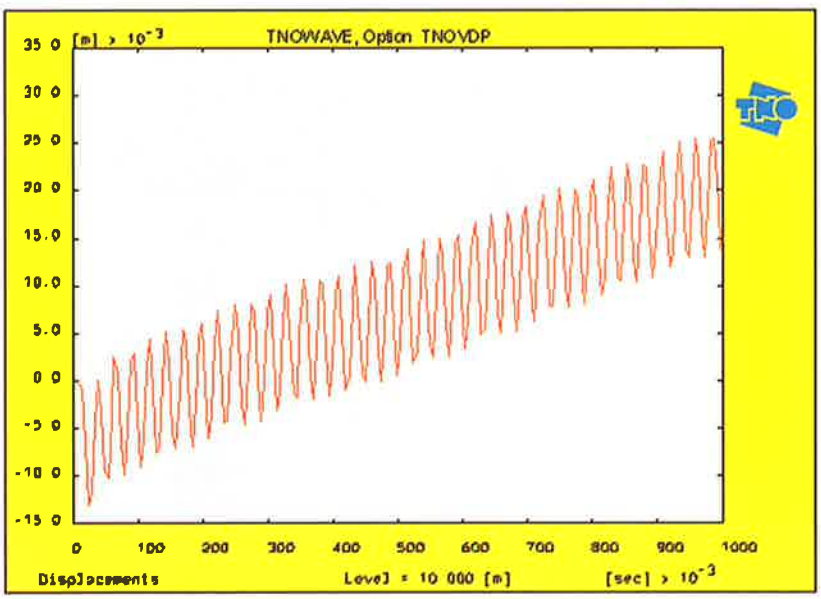


Vibratory driving prodiction results: displacement. at pile toe.

The SPT Controller

Improves the Reliability (Energy Transfer) of SPT Hammers

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

To control the energy transfer during a Standard Penetration Test (SPT) TNO has developped the SPT Controller. The equipment is based on an FPDS system combined with an instrumented SPT driving rod. Additional results similar to Pile Driving Analysis can be obtained.

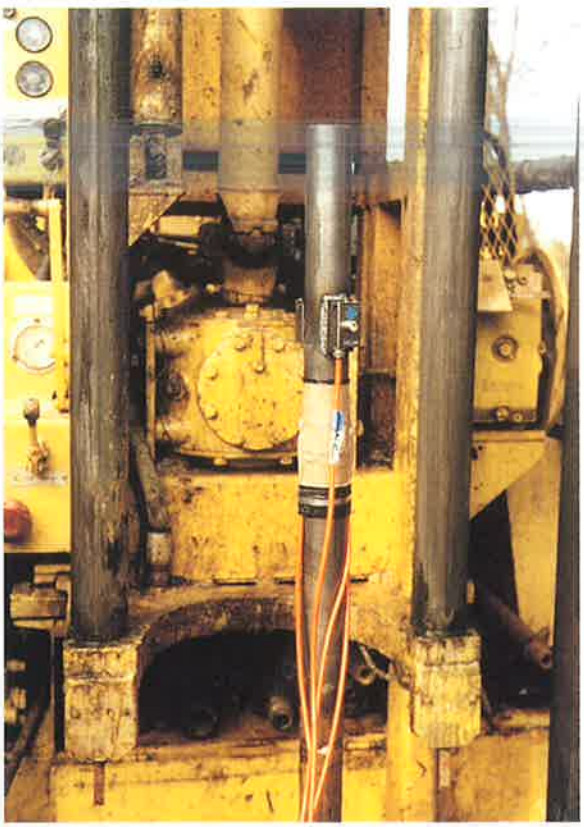
The Standard Penetration Tests (SPT) is used worldwide to a greater extend than any other in situ test. The purpose of this test is to obtain an indication of the relative density of sands and gravels. However it can also used to obtain an indication of the character of silts, clays and weak rock. Engineering applications of SPT results include: determination of settlement of granular soils, estimation of liquefaction potential, compaction control and bearing capacity of piles.

The SPT equipment (ASTM D1586, Eurocode 7) comprises a split tube (sampler) with a driving head to recover disturbed soil samples. The head of the tube is threaded for connection (via a series of drive rods) to a hammer. The device is driven into the ground at the base of the borehole with a free falling 63.5 kg trip hammer dropping a distance of 760 mm. In this way the rated energy of the trip hammer is stadardized (E_r). During the SPT a count is made of the number of blows required to drive through an initial 150 mm, and a subsequent 300 mm test zone. The blow count for the full 300 mm test zone is termed the N-value. Because of friction, design characteristics and other factors, only a part of the rated energy (E_r) will be transferred to the drive rods (E_t).

The N-values are used by design engineers in emperical formulae which assume standardized test conditions. Disadvantages of the SPT test are: the sensitivity to operator techniques, equipment malfunctions and poor boring practice. It has been proven that operator techniques have a strong influence on the energy transfer and resulting N-values. Lower transferred energies will result in higher N-values. (Semi) automatic trip hammers make more consistent test results. However, there are many types of trip hammers each with a different design and resulting impact velocities.

To overcome the variations in transferred energies a standard N_{60}-value is defined (ASTM D4633, Eurocode 7). The N_{60}-value is the N value measured in the field (N_{field}) adjusted by calibration to a reference energy E_r of 60% (E60) or:

$$N_{60} \times E_{60} = N_{field} \times E_{measured}$$



The driving of an SPT rod is very similar to the driving of piles. Thus, the FPDS systems used for Pile Driving Analysis can been easily modified to perform similar measurements on SPT driving rods. This option on the FPDS system is called SPT Controller (SPTC). To measure the transferred energy a dedicated instrumented rod has been designed. The reusable rod is instrumented with strain gages and two piezoresistive accelerometers.

Most SPTC results are similar to those obtained with standard Pile Driving Analysis and other results are included:
- driving resistance;
- transferred energy;
- N-value;
- N_{60}-value;
- static and dynamic soil response.

SPT driving control parameters and signals are presented real time. Measured signals and calculated results are stored on hard disk. Reporting software is included and allows postprocessing and reporting.

The SPTC system is easy to use as it incorporates the following:
- easy to understand menu driven software;
- signals and calculation results are stored automatically;
- number of files to be stored only limited by capacity of hard disk;
- automatic file management;
- extensive reporting options. Data can be printed or plotted on HP plotters or laser printers with HPGL emulation;
- either SI or English Units for input data and results;
- easy extension with other FPDS application like SIT, PDA, STN, VIBRA.

Equipment
- 2 strain channels, intrumented drive rod;
- 2 high quality piezoresistive accelerometers (5000 g, 5 KHz);
- raw signals (acceleration, strain), 4 channels, max 4096 datapoints per channel stored on hard disk;
- high quality, full digital processing (no analogue integrators);
- sample frequency 50 Khz;
- automatic balancing and signal amplification;
- rugged instrumented drive rod;
- modular systems which allows easy maintenance;
- ready to use in minutes;
- one year warranty;
- optional maintenance contract.

Hardware
- SPTC available on FPDS-4 (rugged lunchbox type 486 computer, see separate leaflet);
- SPTC available on FPDS-5, which works in combination with almost any notebook computer supplied with a PCMCIA slot (486, Pentium, see separate leaflet).

Advantages
- supported by a large research organisation;
- competative pricing especially when combined with other FPDS options;
- training at TNO or the users locaton.

Specifications subject to change without notice.

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The Pile Driving Controller

A new tool in pile driving quality control

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

The Pile Driving Controller (PDC) is used to control the quality of the pile driving process in a more automatic way. The PDC consists of a micro computer (FPDS-α), a penetration transducer and a transducer for counting the blows. The PDC can be used to assist the supervisor or can be installed permanently in a rig and operated by the rig operator. No transducers are mounted on the pile and interference with pile driving activities is reduced to a minimum.

For measuring pile penetration special instrumentation has been developed. The penetration transducer is mounted on the lead of the rig. Besides measuring the blow count and the blow rate the PDC can also be extended with options for measuring the rake of the beam, the impact velocity of the ram of instrumented hammers and driving induced vibrations. In combination with pile driving prediction and/or pile driving analysis an indication can be given about the capacity of the pile.

Application

The Pile Driving Controller strikes a balance between technology and operator skill. On one hand the system remains simple to operate within the training of existing personnel. On the other hand it provides information that could not other wise be obtained without significantly slowing the pile driving process.

The registered information can be used to :

- control the pile driving process;
- prove the quality of the driven piles;
- collect and retrieve production data.

Advantages

The advantages of automatic pile driving are thus that:

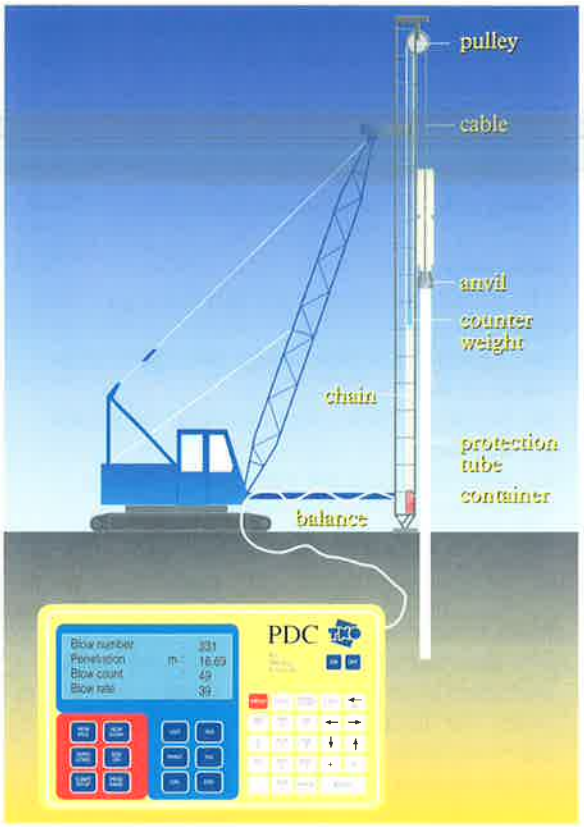
- the registration of information takes place in an objective way;
- the drawing of blow count marks on the piles is not necessary;
- the supervision and the pile driving crew are relieved from dull repetitive tasks;
- there is an automatic registration for the full length of each pile.

Main functions

The main function for the PDC is based on the traditional control of the determination of the blow count. For this reason the device registers the following for the full pile length:

- the penetration depth;

PDC microcomputer (FPDS-α) installed in a rig.



PDC and penetration measurement principle

- the blow count;
- the blow rate;
- starts and stops of driving;
- events like the mounting of a new cushion or an add on.

Additional options

Besides its main functions, the PDC can be extended with functions for the measurement of:

- the rake of the beam;
- the measurements of the impact velocity of
- instrumented hammers;
- the measurement of vibrations to prevent damage or nuisance during pile driving.

Registered input data

Besides the registration of the above data, the PDC also allows the input of the following :

- pile numbers;
- pile dimensions;
- the name of the building site;
- information about three rig;
- information about the pile driving hammer;
- the name of the pile diving contractor;
- the date of driving;
- the control requirements;
- the use of an add-on;
- transducer data;
- the number of used cushions;
- the condition of the pile head at the end of driving.

Operation

At the building site the PDC can be operated by the supervisor but, in most cases, by the operator of the pile driving rig. Because the operator is primarily concerned with pile driving, its operation must be simple. Thus the above data can be typed in directly at the building site or at the office on a PC and transferred to the PDC.

Once at the office, the supervision engineer or members of management can prepare or process the data of the PDC. This can be done efficiently on a PC since the PDC has been primarily designed to store pile driving information in a user-friendly way. An additional program PDC-Report is available to process the input data and measurement results for the PDC.

Reporting options

The presentation of results can be done in graphical form as driving logs or a report of tables. Depending on the need the following reporting styles are possible:

- a compact overview of the most important results form a building site;
- a brief report per pile for the routine cases;
- an extensive report per pile when problems during driving have occurred of when more information is required;
- a production report per site, working day or pile driving rig.

Technical Data

- running on FPDS-α, a field computer in a watertight and robust housing;
- power supply with rechargeable internal battery (12V) for 8 hours work;
- external power supply (by rig or car battery) also possible;
- data storage in memory up to 5 years;
- data storage for about 250 piles (based on 20 m piles and storage of data every 25 cm);
- presentation on LCD screen with clear text;
- penetration transducer with 30 m steel chain, balance and connection cables;
- serial connector for printing and data transfer to PC.

Specifications subject to change without notice.

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Nr. 026-0496

The Vibratory Driving Controller **VDC**

TNO Building and Construction Research

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The purpose of vibratory driving control

The Vibratory Driving Controller (VDC) is used to perform vibratory driving in a controlled manner and in a more automatic way. The VDC can be installed permanently or temporarily on a rig and operated by the rig operator. No transducers are mounted on the pile and interference with vibratory driving activities is reduced to a minimum.

The registered information can be used to:

- control the vibratory driving process;
- control the operation of the vibratory hammer;
- prevent damage of nearby structures, by controlling the vibrations amplitudes;
- prove that structures did not suffer from excessive vibrations;
- collect and retrieve production data;
- trouble shoot the driving process.

How does it work ?

The vibratory hammer is instrumentated with transducers to measure the eccentric moment, the oil pressure and the hammer acceleration. The vibratory driving controller strikes a balance between technology and operator skill. On one hand the system remains simple to operate for normally trained personnel. On the other hand it provides information that could not be obtained otherwise without significantly slowing down the vibratory driving process. At the building site the VDC can be used by the operator of the vibratory driving rig. Because the operator is primarily concerned with vibratory driving its operation must be simple. Input can be typed in directly at the building site or at the office on a PC and transferred to the VDC.

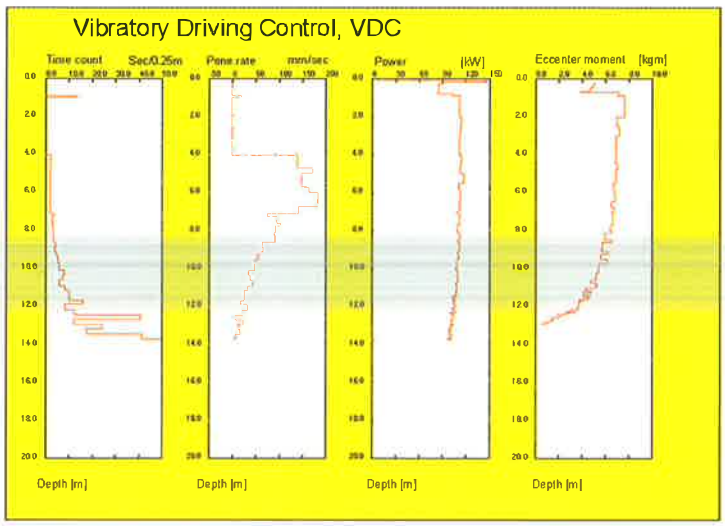
What kind of information is obtained ?

The VDC registers the following for the full pile length:

- penetration depth;
- eccentric moment;
- operating frequency;
- oil pressure;
- hammer acceleration;
- vibrations on nearby structures;
- starts and stops of driving.

From this data the VDC calculates:

- penetration rate;
- time count;
- oil flow;
- delivered power;
- vibratory driving force;
- stresses in the pile;
- total energy.



Vibratory driving control results.

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What other data is registered ?
Besides the registration of the above data, the VDC also allows the input of the following:
- pile number;
- pile dimensions;
- the name of the building site;
- information about the rig;
- information about the vibratory driving hammer;
- the name of the pile driving contractor;
- the date of driving;
- the vibratory driving control requirements;
- transducer data.

What are the advantages ?
The advantages of vibratory driving control are thus that:
- the registration of information takes place in an objective way;
- the supervision and the vibratory driving crew are relieved from dull repetitive tasks;
- there is an automatic registration for the full length of each pile.

The VDC can be extended with functions for the measurement of the rake of the hammer. Measurement data can be stored in memory at predefined penetration intervals or at predefined time intervals, for example every 0.25 m or every 10 seconds. Vibratory driving requirements, like allowable vibrations amplitudes, can be set and will be checked by the VDC.

FPDS-α equipment with vibratory driving control.

What are the equipment components?
The VDC consists of a micro computer (FPDS-α), transducers to measure the eccentric moment, an oil pressure transducer, an acceleration transducers and vibration transducers.

What reporting options are available ?
Once at the office, the data on the VDC can be post prossed. This can be done efficiently on a PC since the VDC has been primarily designed to store vibratory driving information in a user-friendly way. An additional program VDC-Report is available to process the input data and measurement results of the VDC.
The presentation of results can be in graphical form as driving logs, reports and tables. Depending on the need the following reporting styles are possible:
- a compact overview of the most important results form a building site;
- a brief report per pile for the routine cases;
- an extensive report per pile when problems during driving have occurred of when more information is required;
- a production report per site, working day or vibratory driving rig.

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Concrete thickness measurements
THICK

TNO Building and Construction Research

Netherlands Organization for Applied Scientific Research

The purpose of concrete thickness measurements
Concrete thickness measurements have been developed as a tool for the measurement and evaluation of the thickness of slabs and walls which are accessible from one side only. This option can be used for the assessment of the thickness of concrete walls, basement walls and floor slabs of buildings.

This application has also been applied for the detection of the thickness of road pavements. When the thickness of a construction element is known, the system can also be used to evaluate the concrete quality.

How does it work
The principle of the concrete thickness measurement is the determination of the travel time of a compression wave in a concrete slab or floor. The compression wave enters the concrete due to an impulse excitation with the EMH hammer. The wave then reflects from the opposite face of the floor, slab or wall. Both the incident and the reflected waves can be measured by using a sensitive acceleration transducer on the concrete. The elapsed time between the incident and reflected wave is the wave travel time. Stress waves in concrete have a well established propagation velocity, thus the thickness of the concrete part under investigation can be calculated.

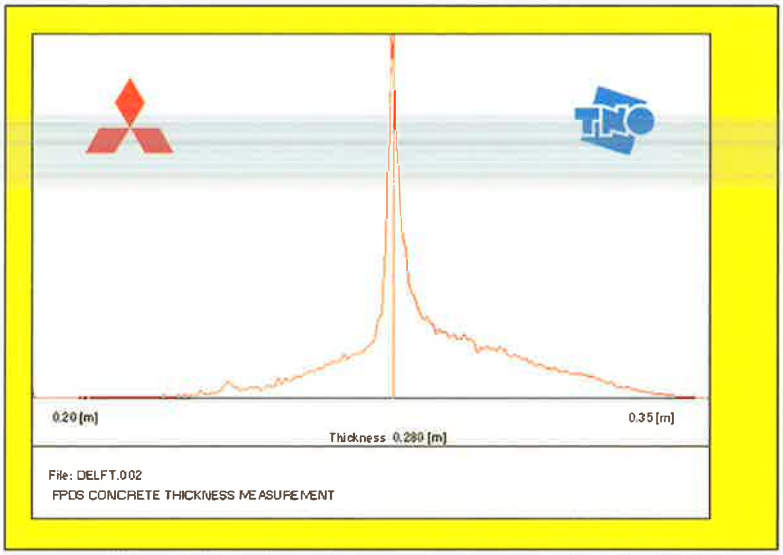
The equipment
The concrete thickness measurement application consists of a specially designed actuator, a dedicated transducer with cable and thickness measurement software.

The pulse actuator consist of an Electro Magnetic Hammer (EMH). The EMH hammer generates a single pulse, a pulse train or a sweep with varying pulse frequencies. The EMH-hammer is a joint development of Mitsubishi Electric Corporation from Japan and TNO Building and Construction Research from the Netherlands.

Concrete thickness measurements are one of the options of the Foundation Pile Diagnostic Systems (FPDS). THICK is supported on FPDS-4 and FPDS-5 systems and the FPDS-6 KIT.

MITSUBISHI ELECTRIC

TNO



Thickness spectrum.

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Interpretation
The elapsed time between incident and reflected waves can be used to determine the concrete thickness. However, multiple reflections will occur and they can be used to advantage. The measured signals can be processed using a fast Fourier analysis to derive the dominant response frequencies. The frequency spectrum can easily be transformed into a thickness spectrum. After processing, the output is presented as a thickness spectrum on the FPDS computer screen. The dominant frequency is related to the thickness of the concrete (see graph).

Electro Magnetic Hammer
The input of the EMH-hammer is one or more pulse shape electrical currents. These pulses are sent through a material with magnetic properties. As a result, magnetic forces will be generated and the material will deform. With a proper design the magnetic material will lengthen within a short period. For each pulse the output of the EMH-hammer will be a single or a series of high energy short duration mechanical pulses. These pulses are of much shorter duration than what can be obtained by other mechanical devices like hand held hammers.

The EMH technology of transferring a current pulse into a mechanical pulse is not new. However research efforts of Mitsubishi Electric Corporation resulted in the design of a composite material generating much stronger mechanical pulses than normally obtained with existing magnetic materials. Energy rich high frequent mechanical pulses are advantageous in many non-destructive applications. The pulses will penetrate deeper into the material, travel over longer distances and generate more detailed information before the energy is absorbed by damping phenomena.

Interpretation, support and maintenance
The interpretation of test results requires a fundamental understanding of the applied technology. TNO conducts instruction courses which are part of the system installation. TNO now organises FPDS user seminars in several geographical regions of the world. TNO also provides support services directly or by fax, E-mail or FTP. Maintenance contracts are available on an annual basis, which include; calibration on sensors, minor repairs, cleaning and free loan systems.

Other applications
For a full list of software applications and particular advantages of each application please consult the appropriate hardware documentation. TNO can provide additional assistance in selecting the best hardware platform for your needs.

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Number 1 April 1996

TNO Building and Construction Research

Foundation Pile Diagnostic Systems NEWS

INTRODUCTION

In 1995, The FPDS (Foundation Pile Diagnostic Systems) group introduced a number of new products into this exciting and rapidly growing market sector. These new products are designed to consolidate and maintain TNO's leadership role. In effect, 1995 was a record year for sales, with TNO FPDS systems being sold in 19 countries and on all continents.

In the last few months there has been a major restructuring of the FPDS products group at TNO. The FPDS group has outgrown both its offices and old organisation struct-ure. To accommodate permanent contact our clients and future growth Dr. Byron Daniels was appointed as our sales manager. Subsequently our telephone and fax numbers have changed. The following telephone and fax numbers will be effective as of March 1st 1996

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Fax:	+31 15 284 3996

Our central E-mail address is FPDS@TNO.bouw.nl

This newsletter can be found on the WWW at the following address, http://www.tno.nl/instit/bouw/home.html

THE MAJOR EVENTS OF 1995

1995 has seen a number of major projects successfully completed, or ongoing. Some of these are listed as follows. Succesful first International Statnamic Seminar, Vancouver Canada, which was organised by Berminghammer and TNO. Information can be found in the Statnamic Newsletter from February 1996. (Available on request).

- A Joint Venture comprising Volker Stevin Construction Europe and Ballast Nedam International installed the driven marine piles in the Central Viaduct of the Vasco da Gama Bridge over the Tagus in Lisbon, Portugal as subcontractor to Novaponte ACE, a consortium of British, French and Portuguese contractors carrying out the design and construction of the new crossing for Lusoponts, SA. Part of this work was pile driving analysis and dynamic load testing by TNO, on steel piles with a diameter of 1.7 meters and lengths between 65 and 85 meters.

Tagus river test site in Portugal.

Statnamic testing.

- Successful application on several sites of the Pile Driving Controller (PDC), amongst which is a large job for the city of Leiden, Netherlands;
- Major Statnamic jobs completed in Malaysia, Japan and the Netherlands by TNO, Berminghammer and our clients.
- TNO's participation at the sixth International conference on Piling and Deep Foundations in Bombay;
- Peter Middendorp also participated in conferences and trade shows in Egypt, Germany (Baugrund Tagung), USA (St. Louis). Paul Waarts was present at the Baltic trade conference in Lituania. TNO was also present at the Offshore Technology Conference (OTC) in Houston (USA) and at the (ISMFFE) conference in Denmark;

our clients to take advantage of all the latest developments.

All clients will obtain the upgraded software versions free of charge.

Upgrade version availability is staggered, with the first new versions to be available soon. Clients will be informed individually as each product is ready for an upgrade. All upgrades will be ready before the end of this year.

Upon upgrading software and manuals for each product, old software versions will no longer be supported by TNO.

REVISION OF MANUALS
In parallel with upgrading software and hardware, all FPDS manuals are being standardised, upgraded and expanded. Past experience is being incorporated by providing examples covering most general questions. All manuals will be written for upgraded software versions only.

MAINTENANCE CONTRACTS AND TRAINING

TNO is committed to give customers with maintenance contracts value for their money. We, and our agents, will stand firmly behind you to ensure that your customers are satisfied with the level of quality of the product that you deliver.

To do this, maintenance contracts are being revised so that they respond better to the needs of our customers. Prices and information on what will be included within future maintenance contracts will be sent to all clients. In the future, maintenance contracts will only be offered to those clients that have successfully completed all necessary training courses. Given the limited resources available it is not possible for TNO to answer questions from customers that have not followed training courses, and that are not familiar with the products they are using. This will ensure that our clients are capable of providing quality services to their customers.

REPORTING OF PROBLEMS, DAMAGES AND DEFECTS
Note that a standard reporting form is provided in this folder on how to report problems, damage and defects with FPDS products.
Completing this form will speed up equipment maintenance and repair.

MAILING INSTRUCTIONS FOR HARDWARE
FPDS units should be insured and mailed in their carrying cases. All external connections should be disconnected. Empty spaces should be filled with foam rubber to prevent components from sliding into each other. The carrying case should be packed into a cardboard box which is filled with Styrofoam chips.

Accelerometers and other small sensitive items should be tightly packed into a rigid cardboard box, firmly taped shut.

Mailing, insurance and customs costs are for the charge of the customer. When sending equipment for repair or replacement, clearly indicate that the contents are for re-export.

SCHEDULE OF EVENTS FOR 1996

Several events are being planned for 1996. Of these the most important is the Fifth International Conference on the Application of Stress-Wave theory to Piles, which will be held on September 11, 12 and 13 in Orlando Florida, USA. On the 14th TNO, Berminghammer and William Loftus & Associates will give a demonstration of the latest pile testing developments followed by informal questions and answers session. We will be demonstrating a Statnamic device with a hydraulic catch mechanism, improved integrity testing techniques and the latest software and hardware developments. Those who are interested in participating in this demonstration are requested to fill in and return the enclosed reply form. Entrance is free of charge.

Training courses for new users and continuing education courses for experienced users will be organised throughout the year. These are possible either at TNO or at your office. In the past we have not published course dates ahead of time, rather each course is organised for individual clients. In the future, however, it may become more efficient to organise courses for user groups according to countries and regions.

COLOPHON

FPDS Newsletter for TNO-FPDS customers, agents and prospective customers.

Subscription to 'FPDS Newsletter' is free of charge. Use of any material in this news letter is subject to prior permission by TNO.

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Cees-Jan Faber and TNO

FEATURES

- hydraulically-operated catch mechanism
- sound proof panels
- calibrated load cell and laser sensor mounted directly on pile
- for augercast piles, precast concrete piles, driven piles, cast in-situ piles and spread footings
    - available on 3 MN, 6 MN, 9 MN models
        - see Berminghammer about retrofitting existing devices

Berminghammer
FOUNDATION EQUIPMENT
A Division of Baltidaniel Inc.

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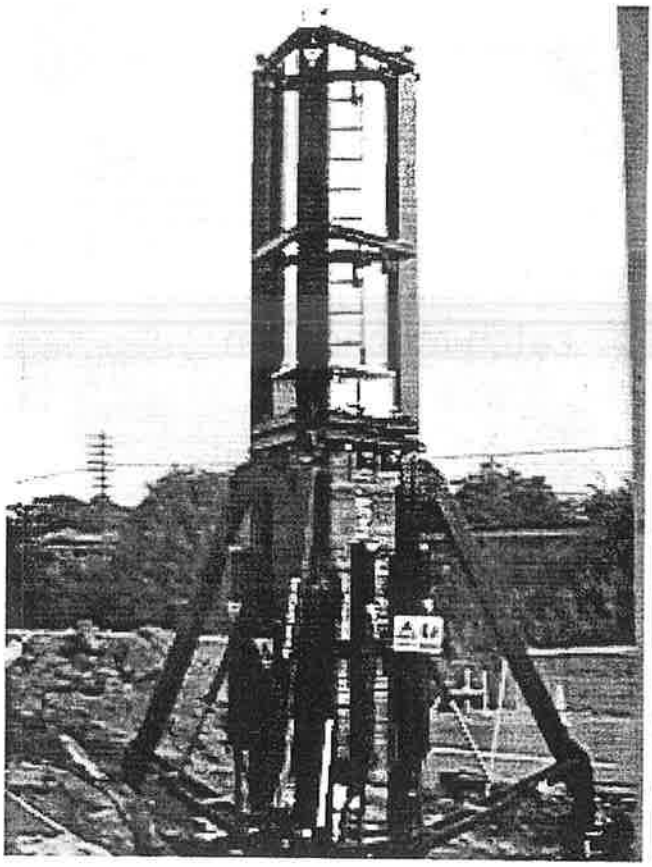
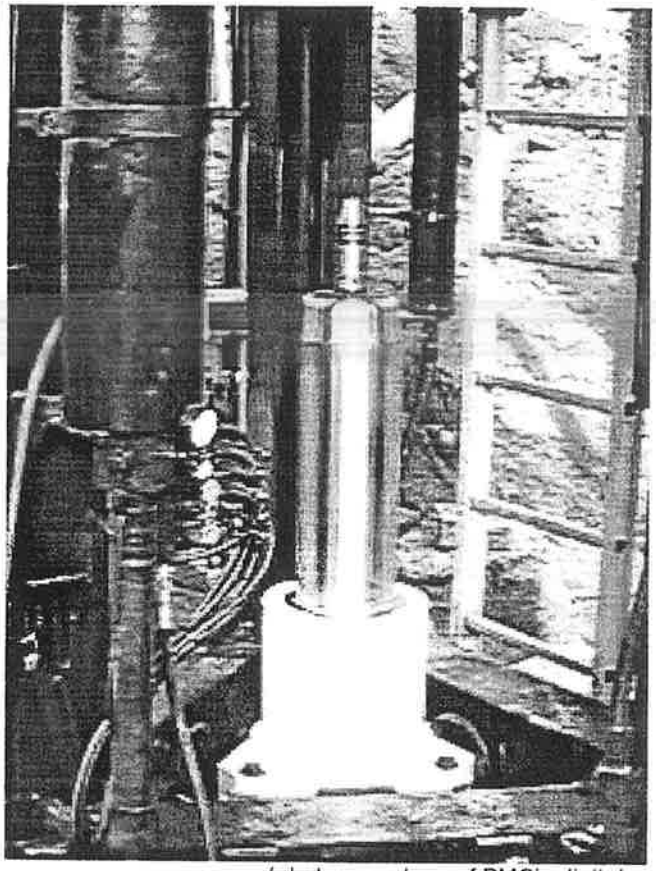
1-800-668-9432
Fax: (905) 528-6187

BERMINGHAMMER ON THE JOB IN ENGLAND





(photos courtesy of PMC's digital camera)

Statnamic 3MN Device with Hydraulic Catch Mechanism Begins Work in U.K.

Precision Monitoring and Control Limited of the United Kingdom recently became the first company in the world to own a Berminghammer Statnamic hydraulic catch mechanism. The first ever Statnamic test in the U.K. was completed on July 17, 1996 followed by two more tests on July 19. The device will conduct several more demonstration tests to introduce the system to piling contractors and consultants, as well as provide an opportunity for PMC employees to become familiar with the device and to streamline their operation. The first contract testing is anticipated in a few weeks.

PMC is an extremely well established and respected pile load testing company specializing in performing static load tests. In 1996 they are anticipating performing over 600 static load tests! With Statnamic they hope to expand their business by capturing some of the existing dynamic load testing market.

The sale of this equipment to PMC offers an excellent opportunity to showcase the performance of Statnamic (and the catch mechanism) to Europe and to the rest of the world.

In a related turn of events, a 16MN Statnamic test is scheduled for Dubai in the United Arab Emirates on September 15 in conjunction with the Middle East office of PMC. The equipment for this test will be supplied by Fugro Japan. We eagerly await the success of Statnamic in both the U.K. and the Middle East.

STATNAMIC

Load Testing Technology

Berminghammer®
FOUNDATION EQUIPMENT

A world leader in foundation testing and construction technology

STAT*NAMIC*:

The accuracy and reliability of static testing without the high costs and long hours.

STAT*NAMIC* is revolutionizing foundation testing in countries all over the world including Japan, Korea, Germany, Holland, Canada, and United States. At a recent mega-project on the east coast of Japan, **STAT***NAMIC* was used to confirm the capacity of three off-shore piles in a critical over-water structure. The three 1.5 meter diameter piles were tested in order to produce a higher of quality control than the static alternative.

The accuracy and simplicity of **STAT***NAMIC load testing provides a cost-effective and efficient means of confirming and optimizing design parameters. One* **STAT***NAMIC test can be conducted in a fraction of the time required for a static load test. Results are produced immediately on site.*

Statnamic: Developed to answer the challenges of today's construction industry.

To satisfy the construction industry's demand for a cost-effective and accurate means of testing high-capacity foundations, Berminghammer Foundation Equipment of Canada joined with TNO Building and Construction Research of the Netherlands to develop **STAT***NAMIC*. Berminghammer, a leading manufacturer of foundation equipment, and TNO, a leading manufacturer of pile testing equipment, bring together years of foundation experience.

Statnamic: A unique design

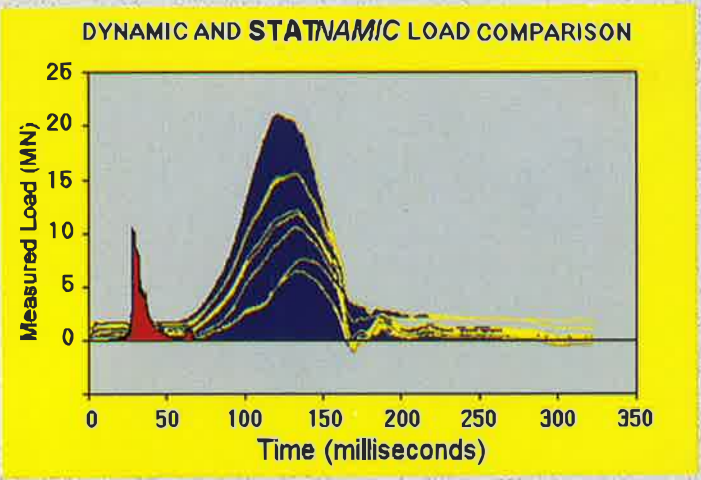
By burning solid fuel in a combustion chamber, **STAT***NAMIC* creates a large pressure acting upward on the reaction mass, in turn producing an equal and opposite force acting downward on the pile. Loading is applied in a linearly increasing manner and a gradual unloading is achieved by controlled venting of the pressure. The duration of **STAT***NAMIC* loading is in the order of 100-150 milliseconds. Rings of concrete or steel provide the resistance — a weight of just 5 percent of the reaction mass in an equivalent static test.

The result: load-displacement behavior almost identical to a static load test.

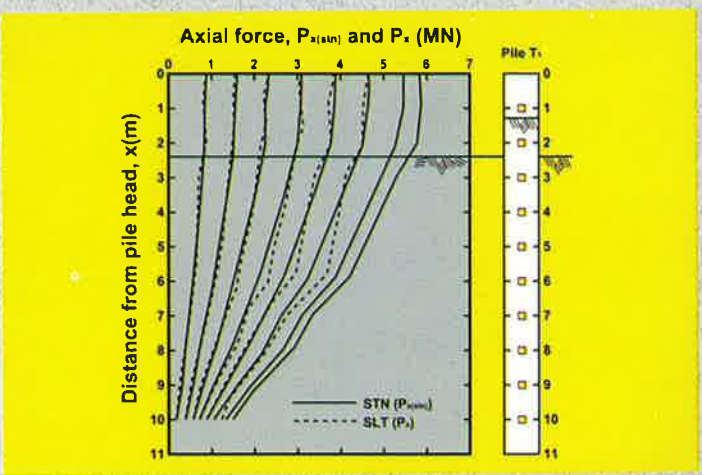
During the entire test, a state-of-the-art load cell and laser sensor, built right into the **STAT***NAMIC* device, act in concert with a high speed laptop computer to measure load and displacement directly. Graphic results are produced immediately onsite with user-friendly software.

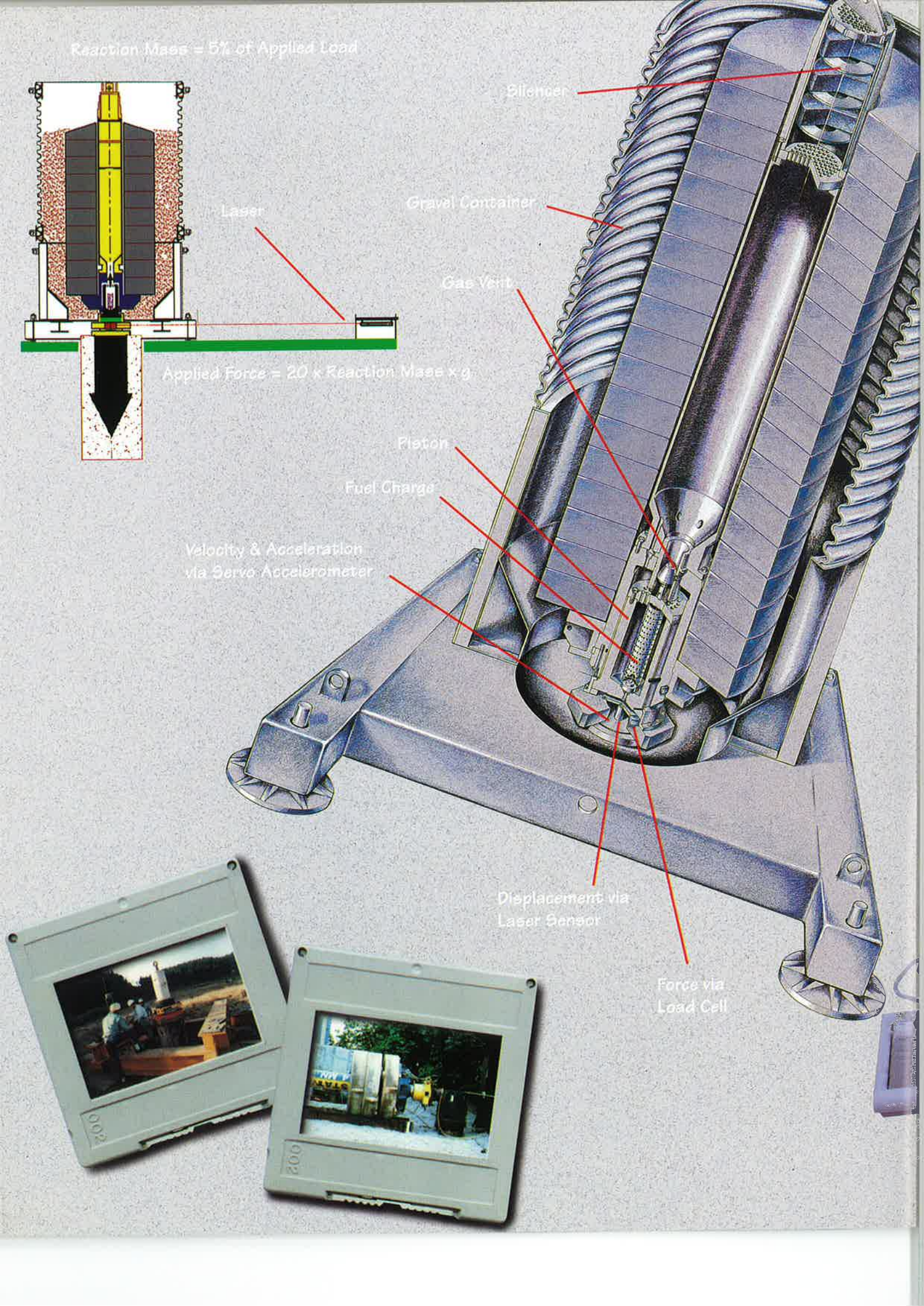
STAT*NAMIC* compared to dynamic and static testing.

Dynamic Testing. In dynamic testing, a falling mass strikes the pile, delivering a short duration impulse. Force and velocity are derived from gauges attached to the pile top. In **STAT***NAMIC* testing, a controlled, pre-determined load is applied directly to the pile without introducing high tension forces. The duration of loading is substantially longer than both the impulse produced by dynamic testing and the natural frequency of the foundation. The capacity of large-diameter foundations can be fully mobilized without risking damage.

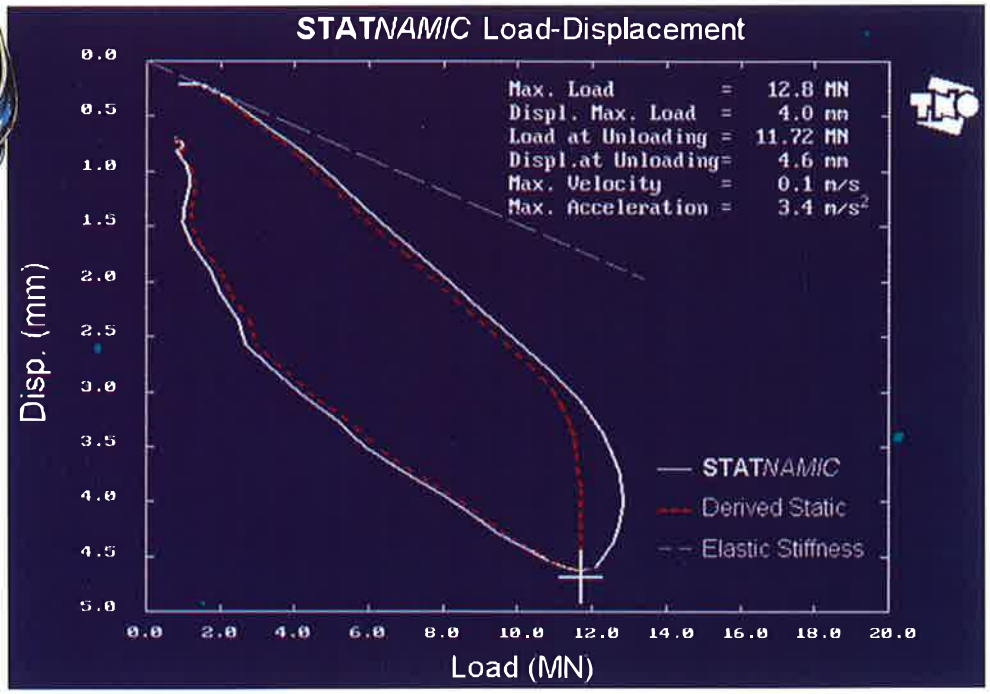


Static Testing. Static testing is expensive and cumbersome. On average, setting up and dismantling a **STAT***NAMIC* test can be done in a single shift without interupting the piling contractor. Multiple piles can be tested in one day. In a comparative program in Kanazawa, Japan, a static and **STAT***NAMIC* test were conducted on the same foundation producing virtually identical load-displacement as well as load-distribution behavior (Figure below). Numerous comparisons on driven and cast in-situ piles have shown similar results.




Reaction Mass = 5% of Applied Load
Laser
Applied Force = 20 x Reaction Mass x g
Silencer
Gravel Container
Gas Vent
Piston
Fuel Charge
Velocity & Acceleration
via Servo Accelerometer
Displacement via
Laser Sensor
Force via
Load Cell

STAT*NAMIC* Results



During a **STAT***NAMIC* test, measured signals from the load cell and laser sensor are digitally recorded by TNO's Foundation Pile Diagnostic System (FPDS). Over 2000 values of load and displacement are recorded. Load versus displacement results are presented immediately on site, as well as graphs of load, displacement, velocity, and acceleration versus time. Straightforward methods of analysis are provided through user-friendly software to determine the damping and inertial effects. Load-deflection behavior and the ultimate capacity of the foundation are clearly presented to the user.

Berminghammer. Breakthrough technology, the result of our commitment to research and our 25 years of experience.

Berminghammer Foundation Equipment has developed a reputation, since its inception in 1969, for leading-edge foundation equipment and for innovative methods of testing foundations. The company's complete commitment to research and development, which has produced breakthrough technologies such as **STAT***NAMIC, has enabled Berminghammer to remain a leader in foundation technology. Vertical Travel Leads have become a industry standard, and Mark 2 and Mark V diesel pile hammers have lead the industry with their high pressure fuel injection, variable energy direct drive, and their ability to use alternative fuels.*

Berminghammer Foundation Equipment is the sister company of Bermingham Construction, a company founded by the Bermingham family in 1897 and now run by a fourth generation of Berminghams.

Every Berminghammer product is field tested by Bermingham Construction before being offered to customers. It's our assurance that each customer enjoys the benefits of our commitment to service and technological excellence.

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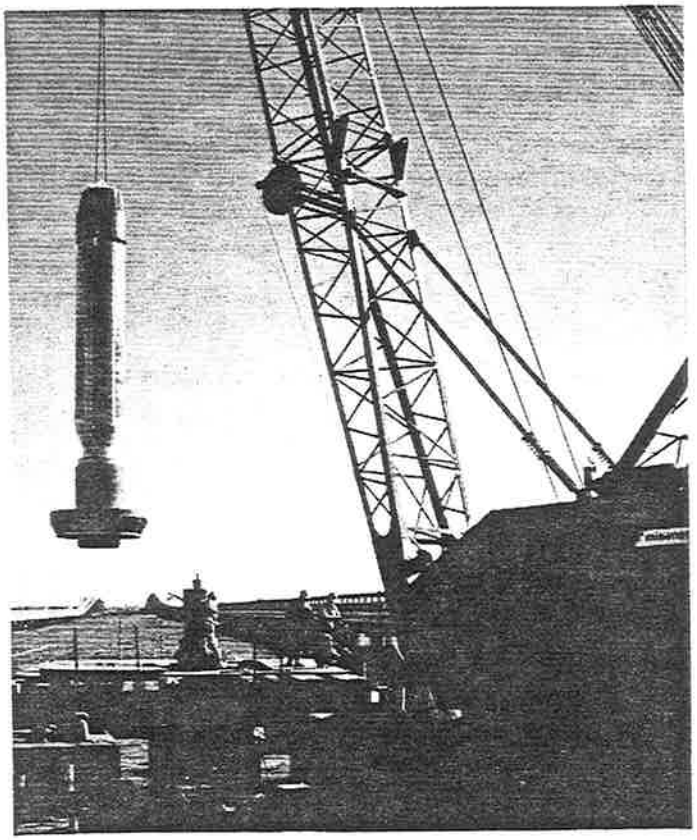
STAT*NAMIC* Overview

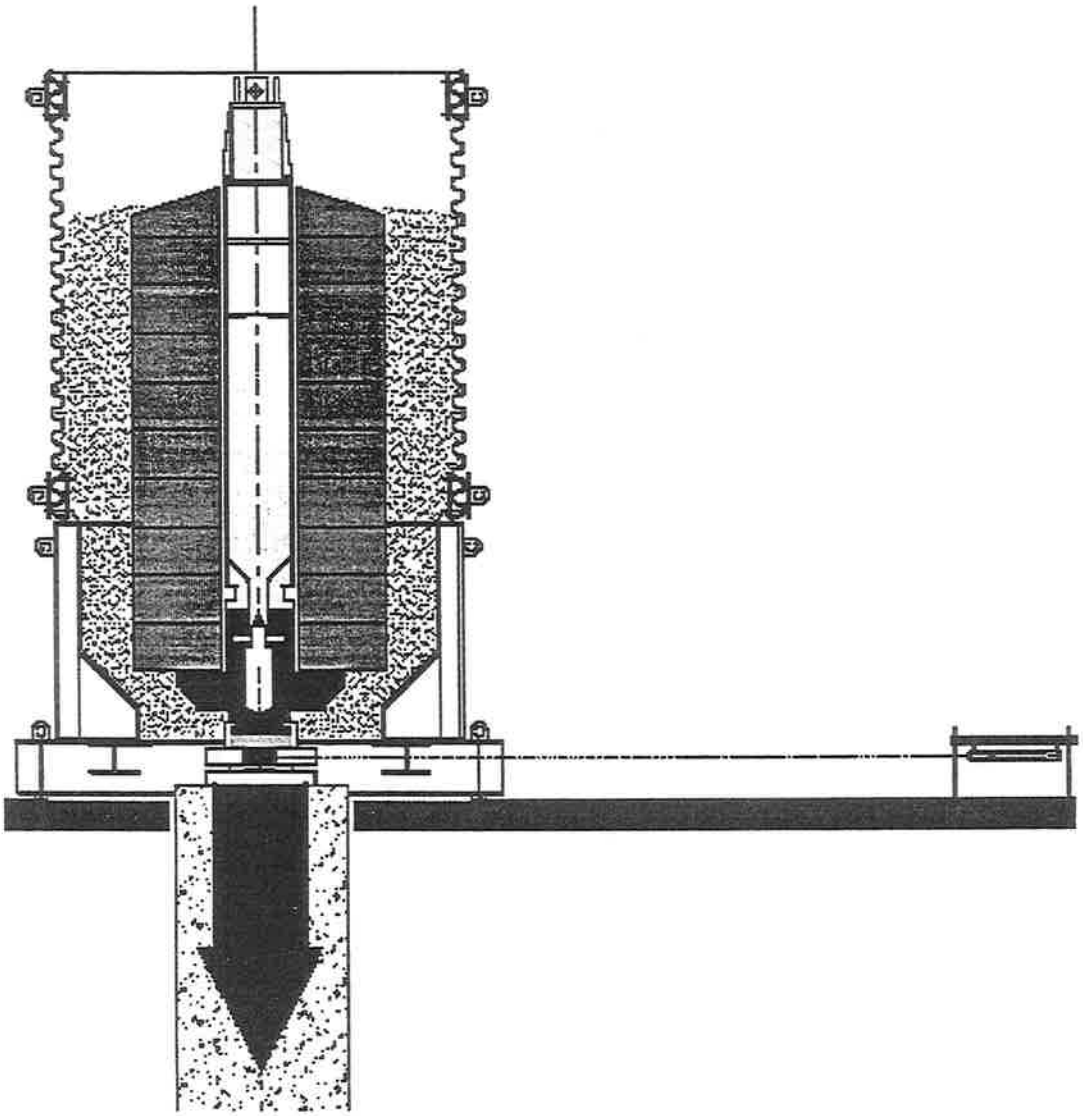
The **STAT*NAMIC*** load test has been developed to meet the construction industry's demand for an accurate and cost-effective method of determining the load bearing capacity of caissons and high capacity piles. Developed jointly by Berminghammer Corporation of Canada and TNO Building & Construction Research of the Netherlands, **STAT*NAMIC*** can be used on any pile type with minimum pile preparation. Loading is perfectly axial and the relatively slow application and release of compressive forces eliminates tensile stresses, compressing the pile and the soil as a single unit. As a result, static load-displacement behaviour can be obtained.



STAT*NAMIC* Assembly

Conventional static load testing methods for deep foundations are expensive, time consuming, and cumbersome. Dynamic load testing methods do not provide direct measurements, induce high accelerations, and load-displacement behaviour is controlled by the action of stress waves. **STAT*NAMIC*** testing overcomes the practical difficulties of both static and dynamic load tests.

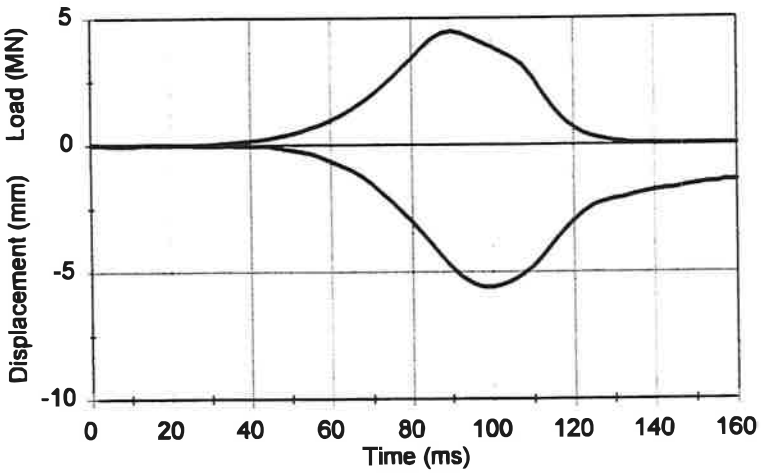
In **STAT*NAMIC*** testing, solid fuel is burned within a pressure chamber. As the pressure increases, an upward force is exerted on a set of reaction masses while an equal and opposite force pushes downward on the pile. Loading increases to a maximum before unloading by a controlled venting of the pressure. Built-in instrumentation (load cell and laser sensor) record load and displacement during the entire **STAT*NAMIC*** test.



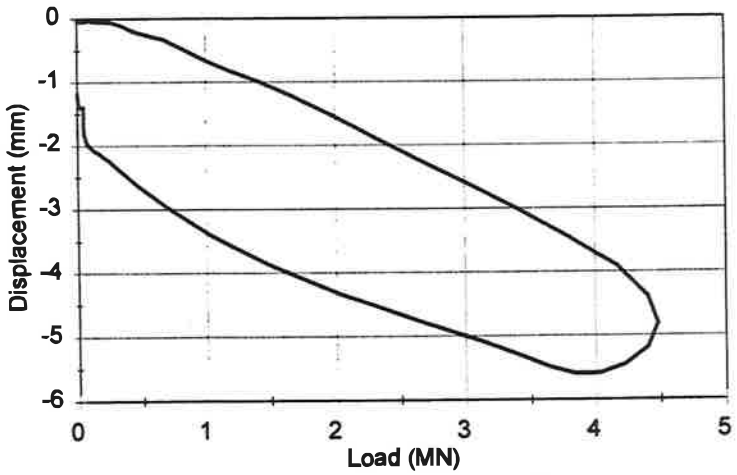
The STAT*NAMIC* Device

STAT*NAMIC* assembly is straightforward. All components are handled with a small hoisting machine. Reaction masses are sectional (2400 kg for the 5 MN device) and made of concrete, lead, steel, etc. Concrete reaction masses can be cast on-site and reused.

During a **STAT*NAMIC*** test, measured signals from the load cell and laser sensor are digitally recorded by TNO's Foundation Pile Diagnostic System (FPDS). Over 2000 values of load and displacement are recorded. Load versus displacement results are presented immediately on-site, as well as graphs of load, displacement, velocity, and acceleration versus time. Straightforward methods of analysis are provided through easy-to-use software to determine any damping or inertial effects. Load-deflection behaviour and the ultimate capacity of the foundation are clearly presented to the user.



Measured STAT*NAMIC* Signals



Load versus Displacement

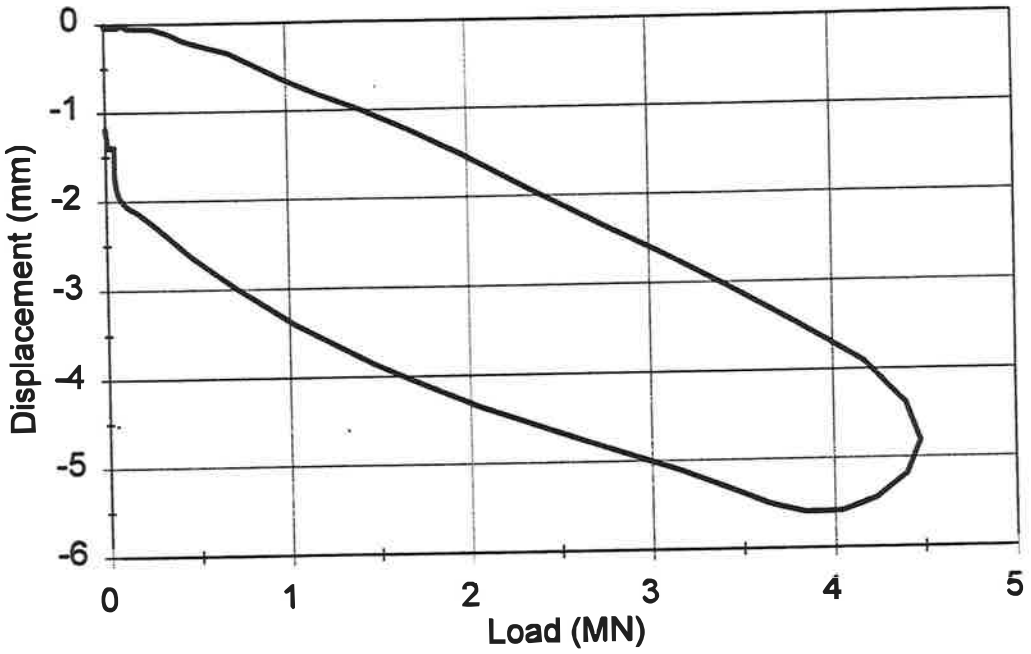
In the example above, the **STAT*NAMIC*** test mobilized the full capacity of the pile, providing 1.2 mm of net settlement.

Berminghammer, TNO Description

Berminghammer Foundation Equipment is a privately-held member company of the Bermingham Group. Berminghammer manufactures foundation installation equipment, providing high-quality tools for its construction division. Since 1969, Berminghammer has become known for high-quality equipment, focusing on leading edge technology and strong research and development. Innovative products include the Vertical Travel Leads (more piles can be driven from a single crane location) and Direct Drive pile hammers (delivering twice as much energy to the pile top than conventional hammers.) In 1987, Berminghammer began **STAT*NAMIC***; a four-year program to produce a revolutionary load testing method for high capacity piles. The first **STAT*NAMIC*** test in 1988 produced results almost identical to a static load test at a fraction of the time and cost. Today, **STAT*NAMIC*** tests loads up to 30 MN.

As part of the **STAT*NAMIC*** project, Berminghammer formed a partnership with The Institute for Building and Construction Research of The Netherlands Organization (TNO). TNO is involved in research and development projects for building industry firms, government agencies, material suppliers, and others, specializing in materials, building technology, and structural engineering. For **STAT*NAMIC***, TNO developed and manufactured the Foundation Pile Diagnostic System (FPDS), the computer interface used in all **STAT*NAMIC*** tests. Using state-of-the-art instrumentation, FPDS provides load-displacement histories immediately on-site. FPDS provides a number of other options for pile testing, including sonic integrity testing, dynamic load testing, and stress wave simulation.

1.0 Introduction to STAT*NAMIC*



Today's taller buildings, heavier loads, and increased construction costs require the use of large-diameter, drilled pier foundation systems. As such, the demand for high capacity piles over 5.0 MN has increased dramatically.

Traditionally, static pile loading tests (to failure or twice design load) have been used to verify the geotechnical design parameters, pile load capacity, and, in some cases, the integrity of the pile. However, static pile loading test methods are expensive, time consuming, and cumbersome. Dynamic load tests have been used, as well, to predict static capacity and load-displacement behaviour. The dynamic response of a pile, however, is controlled by stress waves; the analysis of which requires highly-experienced engineers. Dynamic load testing also creates tensile stresses which can cause pile damage in concrete piles.

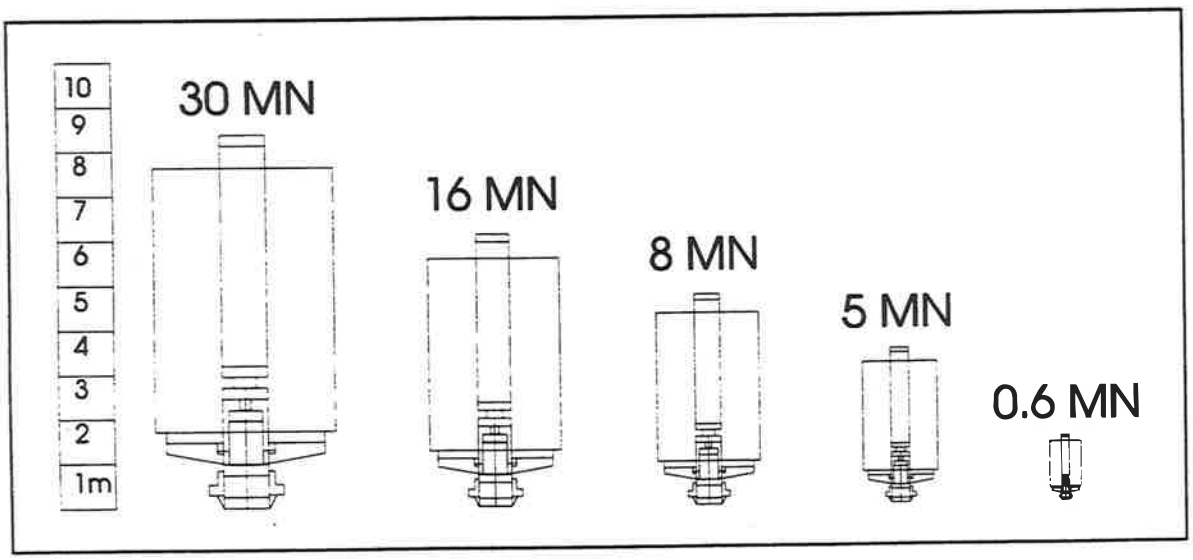
STAT*NAMIC* testing overcomes the practical difficulties of both static loading and dynamic load tests. **STAT*NAMIC*** is capable of producing a given force using only 10% of the mass in an equivalent static test. During **STAT*NAMIC*** loading, a perfectly axial load is applied for a duration of 120 milliseconds; long enough to compress the entire pile. Pile behaviour is not dominated by stress wave propagation and pile accelerations are on the order of 1 g. Load duration and loading rate are controlled by the vent height, amount of fuel, and reaction mass.

1.1 Development Background

STAT*NAMIC* development began in 1988 with a 0.1 MN test device. Today, test devices are capable of producing loads up to 30 MN.

Equipment Range	
1988	0.1 MN
1989	0.6 MN
1990	5.0 MN
1991	8.0 MN
1992	16.0 MN
1994	30.0 MN

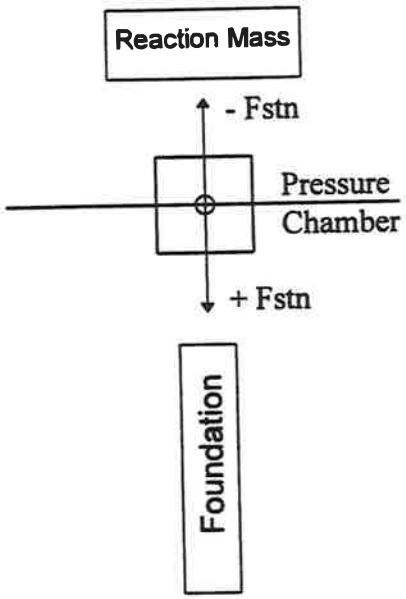
STAT*NAMIC* load tests have been conducted in Canada, United States, Netherlands, Japan, Germany, Israel, and Korea. Testing options include single piles, pile groups, structural elements, bridge piers, and spread footings.



STAT*NAMIC* Loads up to 30 MN

1.2 Basic Concepts and Physics

The **STAT*NAMIC*** device is placed directly atop the test pile. Solid fuel is burned within a pressure chamber, creating a large pressure which drives the reaction mass upward. An equal and opposite force pushes downward on the pile.



STATNAMIC Physics

If a reaction mass of 30 tonnes is initially accelerated upward at 20 g, then a resultant 600 tonne force acts downward on the foundation. The reaction mass is 1/20 (30 tonnes/600 tonnes = 1/20) or 5% of the equivalent **STAT*NAMIC*** mass. **STAT*NAMIC*** loading is applied in a linearly increasing manner and gradual unloading is achieved by a controlled venting of the pressure. The duration of force is on the order of 120 milliseconds.

Pile accelerations of 1 g are 100–1000 times less than a conventional dynamic load test. As well, the duration of force is 10 to 20 times greater than a conventional drop hammer blow. Thus, pile behaviour is not dominated by stress wave propagation. A dynamic load test is a shock load whereas a **STAT*NAMIC*** load can be compared to a push, subjecting the pile to consistent, high compressive forces throughout the length of the pile.

STAT*NAMIC* can be described using each of Newton's three Laws of Motion:

1st Law (Law of Inertia)

A body will continue in a state of rest or uniform motion unless compelled to change that state by an external force.

$$\Sigma F = 0$$

In a load test, two external forces act on a pile—the loading force which sets the pile in motion and the pile's resistance to that motion. Pile resistance is primarily a function of the inertia of the pile mass due to pile stiffness and soil stiffness along the pile shaft and at the pile toe. By measuring the pile displacement during test loading, a measurement of the pile's resistance and thus the pile/soil behaviour can be measured.

2nd Law (Law of Acceleration)

When acted upon by an external force, a body accelerates in the direction of that external force and is proportional to the magnitude of that force.

$$F = ma$$

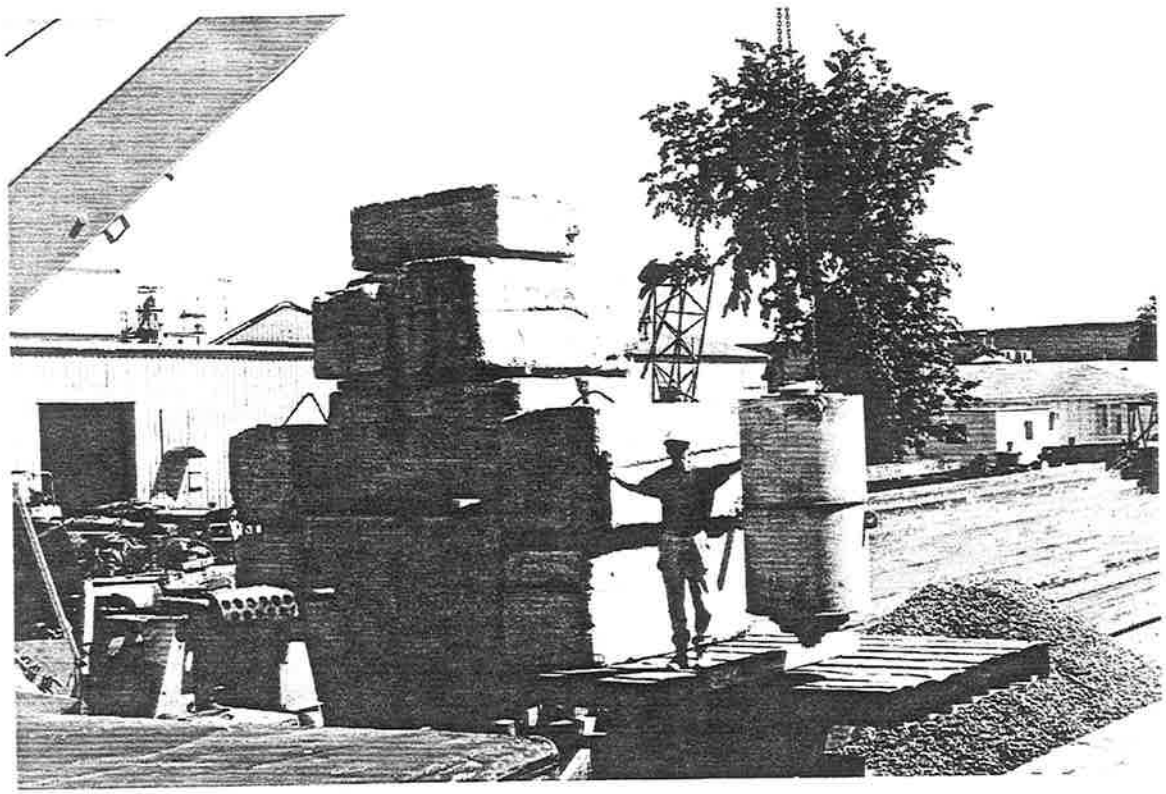
In static, **STAT*NAMIC***, and dynamic load testing, the same net force can be applied to a pile by different means. Compare:

Static: $F = M \times g = Mg$

STAT*NAMIC*: $F = \frac{M}{20} \times 20g = Mg$

Dynamic: $F = \frac{M}{500} \times 500g = Mg$

where M is the total mass of a static test,
M/20 is the reaction mass (**STAT*NAMIC***),
M/500 is the drop hammer mass,
g is the acceleration due to gravity,
20g is the acceleration of the reaction mass (**STAT*NAMIC***),
500g is the acceleration of the drop hammer



Static Mass Beside an Equivalent STAT*NAMIC* Mass

3rd Law (Action and Reaction)

For every action there is an equal and opposite reaction.

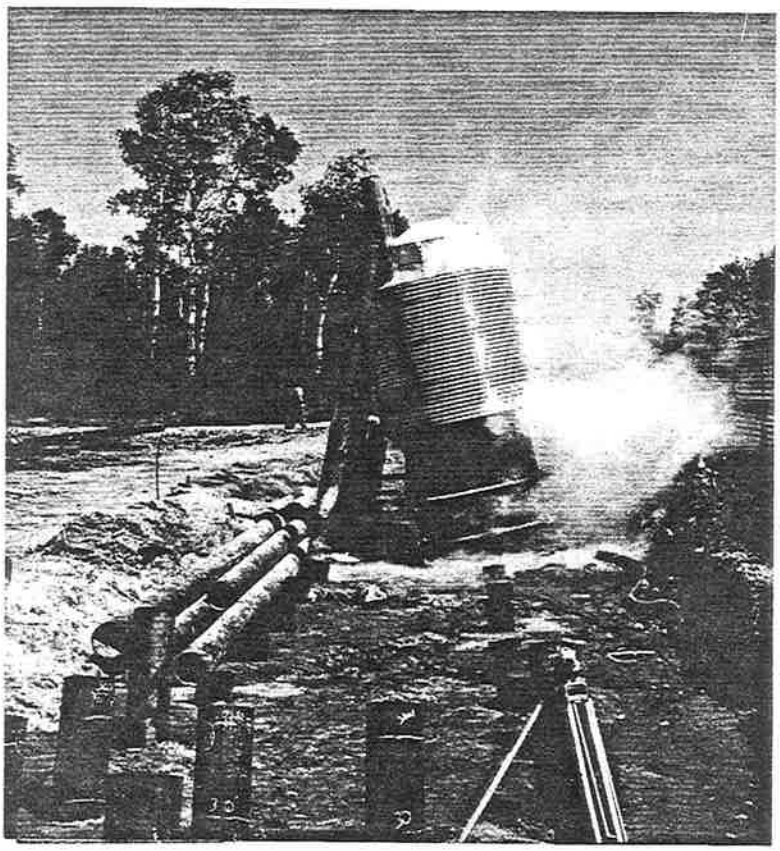
$$F_{12} = -F_{21}$$

During **STAT*NAMIC*** loading, the pressure vessel exerts an upward force on the reaction masses, while an equal and opposite force reacts downward on the pile. Furthermore, since the direction of force is along the cylinder assembly, loading is perfectly axial.

1.3 Applications

STAT*NAMIC* can be used on any pile type or structure:

- micro piles
- batter piles
- pile groups
- caissons
- piles
- lateral load tests
- bridge piers
- spread footings



1:3 Batter Pile Test

STAT*NAMIC* Advantages

- **STAT*NAMIC*** applies loads up to 30 MN (3,400 tons).
- Foundations tested include high capacity drilled shafts,
  steel piles,
  augercast piles,
  timber piles,
  batter piles
  in clay, rock, silt, and sand.
- **STAT*NAMIC*** can test bridge foundations, pile groups, spread footings, and off-shore piles.
- **STAT*NAMIC*** can test the lateral capacity of foundations.
- Production piles can be tested without prior planning. No reaction piles are required.
- Three 600 ton tests can be conducted in one day shift.
- Several **STAT*NAMIC*** tests can be conducted for the cost of a single static test.
- **STAT*NAMIC*** loads the pile and soil together.
- The duration of loading is on the order of 10 Hz
- **STAT*NAMIC***'s built-in load cell and laser sensor provide direct measurements of load-displacement behaviour.
- **STAT*NAMIC*** produces load-displacement results immediately on site.

2.0 STAT*NAMIC* Theory

2.1 Load Duration

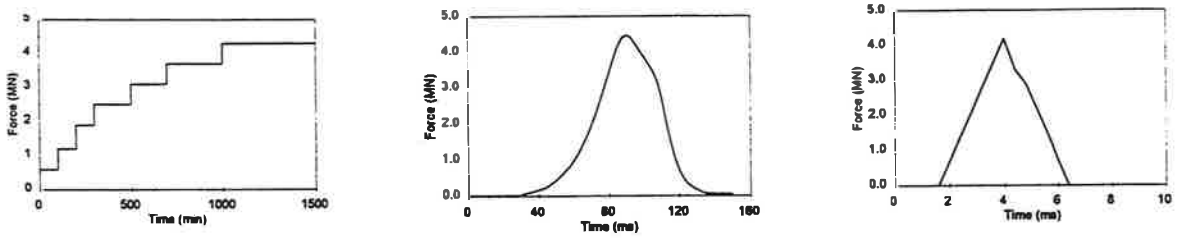


Figure 2.1 Static Loading, STAT*NAMIC* Loading, Dynamic Loading

- **Static Loading**

Since velocity and acceleration are near zero throughout a static load test, damping and inertial effects are minimal. However, as the load duration decreases for quick static load tests, results can differ from conventional static tests due to the strain rate-dependent nature of soil. Low permeability soils (soft silty or clayey soils) are most susceptible to quick load rates.

- **Low Rate Dynamic Loading** (STAT*NAMIC*)

The duration of pile loading is on the order of 120 milliseconds. The load duration, while not on the order of static testing, is still relatively long compared to high rate dynamic testing. Dynamic rate effects are present only in low permeability, cohesive soils and can be accurately measured using existing pile/soil models.

- **High Rate Dynamic Loading** (Dynamic Load Tests)

The duration of pile loading is on the order of 4 milliseconds. The short duration of loading introduces stress waves to the pile and will unduly effect pile/soil behaviour. Damping and inertial effects exert a strong influence on the test result and are difficult to quantify.

2.2 Stress Wave Mechanics

In conventional static loading, the pile compresses as a whole throughout loading and can be considered as a rigid body. As the load duration decreases, however, stress waves are introduced to the pile, effecting pile/soil behaviour. Stress waves propagate along the pile at the speed of sound within the pile.

$$c = (E/\rho)^{1/2}$$

where c = stress wave velocity
E = pile/soil system modulus
ρ = pile/soil system density

C is about 3500 to 4000 m/s for reinforced concrete piles and 5000 m/s for steel piles. For long piles (≈30 meters) an initial stress at the pile top will reach the pile toe in approximately 6 milliseconds, corresponding to the pile's natural period. (30/5000 = .006)

STAT*NAMIC* loading is on the order of 120 milliseconds, well above the natural period of even the stiffest pile. Because stress wave effects are minimized, the pile can be considered as a rigid body and conventional static analytical methods apply. Although results from **STAT***NAMIC* load tests have shown that rate effects are negligible for piles in very stiff soils and piles end-bearing in rock, rate effects for piles in soft soils have been relatively large and have significantly influenced load-displacement behaviour. The Unloading-Point model, as described below, is a simple method of analysis for determining the static resistance from a **STAT***NAMIC* test. As well, rate effects present during a **STAT***NAMIC* test can be quantified with the Unloading-Point model.

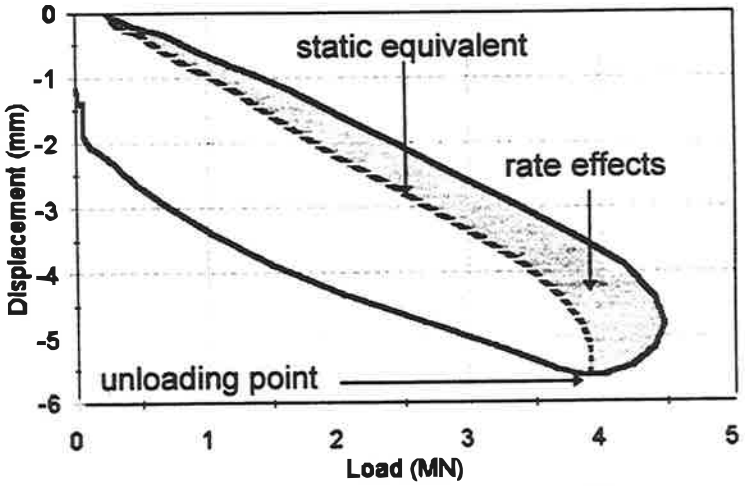


Figure 2.2 $F_u(t)$ versus u(t)

2.3 Pyrotechnics

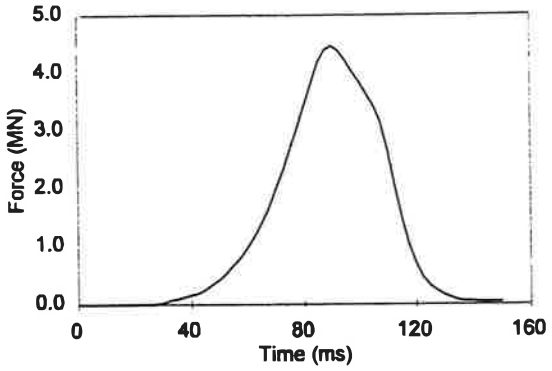


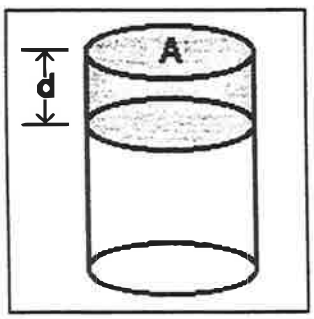
Figure 2.3 STAT*NAMIC* Loading

To produce the characteristic **STAT*NAMIC*** loading (force versus time as shown above), the pressure chamber expands due to the increasing pressure from burning fuel gases. The **STAT*NAMIC*** cylinder, located on top of the pressure chamber, is accelerated upward at a rate proportional to the increase in pressure. The upward force (and hence the downward **STAT*NAMIC*** loading) is equal to the product of this acceleration and the total reaction mass. Thus,

$$F = ma \qquad (1)$$

where $a = C_1 \cdot t$
and C_1 is a constant.

The increased volume of the pressure chamber is equal to the product of the displacement of the cylinder (d) and the area of the pressure vessel (A). Thus,



$$V = A \cdot d = A \iint a \cdot dt$$
$$V = A\,(C_1 \cdot t^3 + C_2 \cdot t^2 + C_3 \cdot t) \qquad (2)$$

where a is integrated twice in equation 1 to determine d.

The rate of increase in pressurized gas production is therefore cubic, characteristic of solid propellant fuel.

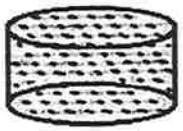


Figure 2.4 STAT*NAMIC* Fuel

The **STAT*NAMIC*** fuel consists of a number of small, perforated solid pellets. The burn rate depends on several parameters:

1. chemical composition,
2. pellet geometry,
3. temperature,
4. pressure.

Chemical composition is chosen from factory burn trials. Perforated cylindrical pellets are preferred to solid pellets or flat plates because they increase in surface area throughout burning as desired for **STAT*NAMIC***. Furthermore, using many small pellets instead of one large fuel charge produces a consistent burn and averages out any imperfections in a single pellet. As expected, the natural burn rate increases as temperature and pressure increases in the pressure chamber. Under normal operating conditions, burning will not begin until the fuel temperature reaches 1000 °C.

The **STAT*NAMIC*** propellant can be safely handled and will not ignite under spark, friction, or agitation. When ignited under atmospheric conditions, the burn is slow and easily controlled. The fuel can be extinguished with water. Propellant can be transported with minimum preparation and stored for long periods of time without concern.

From formal tests as outlined in the U.N. Transport of Goods, the fuel is classified as U.N. Class 1.4.

2.4 Data Acquisition

Load and displacement data are measured at the pile top with a calibrated load cell and laser sensor and analyzed by TNO's Foundation Pile Diagnostic System (FPDS.) The load measurements are accurate to within 0.1% and the displacement measurements are accurate to 0.1 mm. A total of 2000 data points are recorded at a sampling rate of 150 microseconds for a total time of 0.3 seconds, suitable to record the entire event. The sampling time and total measuring time are variable and can be changed in FPDS. The ignition triggering is also controlled by FPDS.

Load Cell

The **STAT***NAMIC* load is measured by a circular load cell, located between the piston and the pile top. A number of strain gauge transducers, mounted on the load cell circumference, reduce the effects of any uneven loading. Load signals from each transducer are averaged and amplified within the load cell to reduce error and are further amplified by FPDS.

Laser Sensor

Pile displacement is measured with a photo voltaic laser sensor (located at the centre of the piston base) and a remote reference laser source. During the **STAT***NAMIC* event, the change in position of the laser sensor is measured relative to the stationary laser source. Any ground motion due to loading occurs after the event and does not effect the reference source, 20 meters away.

Throughout loading, load and displacement signals are digitized and written to a raw voltage data file. After the event, the raw signal voltages are converted to load and displacement values using factory calibration values. Load-displacement graphs are presented immediately on-site. Supplementary graphs, including graphs of velocity and acceleration, can also be generated with simple post-processing monitoring commands in FPDS. All data is stored for future analysis and reference.