FOUNDATION TESTING DATA SHEET 1
Pile Integrity Testing – TDR Method

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The Transient Dynamic Response (TDR) test is a rapid method of assessing the integrity of both pre-cast and cast in situ concrete piles. It is a natural evolution of the Steady State Vibration test first developed and applied to foundation testing by J Paquet in 1966. At that time a heavy (25Kg) vibrator was used to excite the pile at a range of frequencies.

Since that time there have been dramatic improvements and miniaturisation of the equipment, the most significant single step coming in 1982 when it was found that identical results could be obtained using a transient impulse on the pile top, using a small hand held hammer acting through a load cell in place of the heavy vibrator. Advances in micro processing meant that the time domain signal could be readily converted to frequency using the Fast Fourier Transform. This technique is now known as the Transient Dynamic Response and testing now only takes about 30 seconds per pile compared to about 15 minutes in 1965. It is now considered by many engineers to be the most appropriate test method for checking bored cast foundations.

Equipment used is lightweight and portable and is very rapid in operation. Analysis of results can be carried out instantly on site to confirm the length of the foundation and depth of any defects if they exist. The TDR system also has a powerful software analysis program, to enable more detailed analysis of changes in pile section and the influence of soil. It can also be used to predict the expected test result before even visiting site! The required preparation is minimal and in normal conditions up to 60 piles per day can easily be tested, increasing to 200 where access is very good.

Geophone sensor

Principle

The method is based on measuring the frequency and amplitude response of a pile known as impulse. This response, known as Mechanical Admittance (or mobility), contains all the information necessary to check pile integrity and to analyse soil influences. At higher frequencies the resonating harmonics of the pile are detected, whereas at low frequency the response is generally linear allowing measurement of pile-head stiffness.

What will it tell you ?

The TDR method of assessing piles is able to analyse acoustic anomalies corresponding to the following :

- ✓ Pile Toe Level
- ✓ Shaft restraints
- ✓ Overbreak
- ✓ Cracks
- ✓ Reductions in section
- ✓ Zones of poor quality concrete

For further information on the advantages and limitation of this technique and other low strain methods of assessing piled foundation, we recommend reading CIRIA report 144 titled 'Integrity testing in piling practice' published in 1997.

Testconsult Ltd
Ruby House, 40a Hardwick Grange
Warrington WA1 4RF
Tel: +44 1925 286880 Fax: +44 1925 286881
Email: iwan@testconsult.co.uk
Web Site: www.testconsult.co.uk

Testconsult Ireland Ltd
Materials Laboratory, Clonminam Ind Est
Portlaoise, Co Laois, Ireland
Tel: +353 502 64885 Fax: +353 502 64380
Email: tom@testconsult.ie
Web Site: www.testconsult.co.uk

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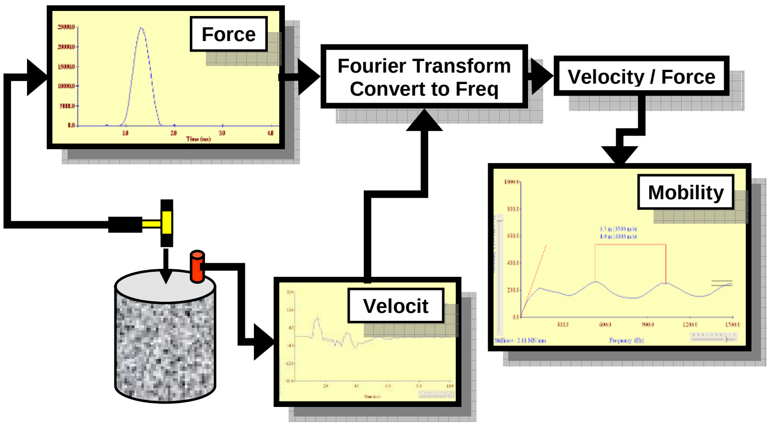


How does it work ?

After ensuring that the concrete in the pile head is visually free of loose material and contaminants, a geophone sensor is placed in contact with the pile head, which is struck axially using the force response hammer. The response of both transducers is measured simultaneously, and these signals, velocity and force, are digitally processed and displayed on the test unit.

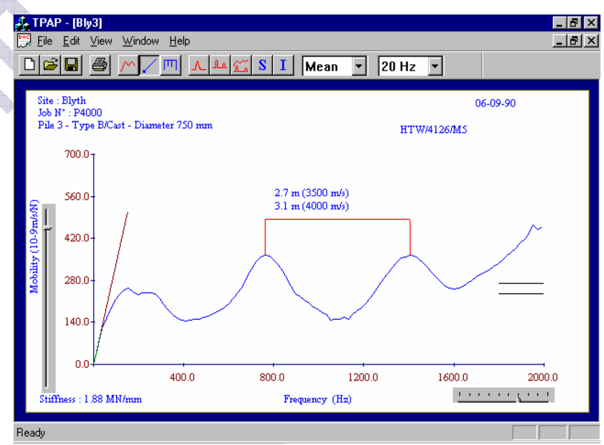
When a pile top is struck with the hammer a longitudinal wave travels down the shaft – it can be likened to a snake swallowing an egg. When the wave reaches the base of the pile it is reflected back up to the top. By assuming a wave speed velocity it is possible to calculate the pile length. Reflections can also be obtained from acoustic anomalies within the pile shaft. At low frequency the response is generally linear allowing measurement of the dynamic pile head stiffness.

Length Measurement

Length measurements are calculated from the distance between resonating peaks, produced by the pile toe or acoustic anomalies along the shaft. Lateral soil restraints, overbreak, changes in shaft section, cracks and zones of poor quality concrete can all produce various types of acoustic anomaly which can be detected.

Length, L = C/2df

Where:
C = velocity of longitudinal waves in concrete
df = distance between two resonating peaks



Typical mobility response

Dynamic Pile Head Stiffness

The dynamic pile head stiffness is measured at low frequencies, when the pile head and surrounding soil are moving as one unit and is the reciprocal of the slope of the initial part of the curve.

Stiffness, E' = 2 pi fm / (V / fm)

Where:
Fm = frequency at point of measurement
V = Velocity

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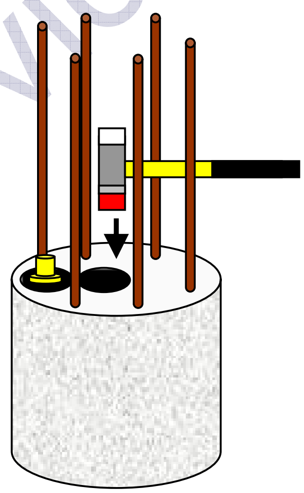
Mobility (inverse of impedance)

Concrete density or conversely the cross-sectional area of the pile (if concrete strength is known) can be calculated from the mean Mobility (N) of the resonating part of the curve using the following formula.

Mobility, N = 1 / pCA

Where:
p = concrete density
C = velocity of longitudinal waves in concrete
A = pile cross sectional area

Pile Head Preparation

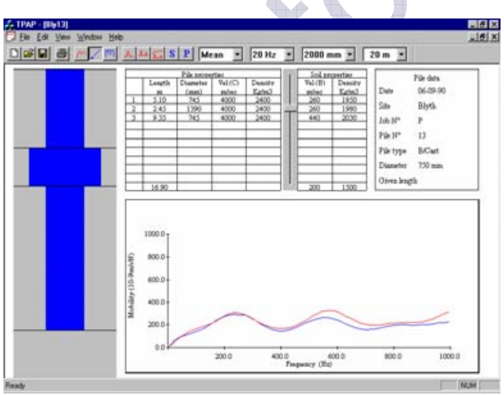


In order the obtain the very best data possible when testing a pile, it is essential that the pile head is prepared properly prior to testing. Without good data any interpretation carried out will be meaningless. It is essential that the measurement transducers are mounted in the correct position and on sound concrete. The essentials of pile head preparation for integrity testing are given below :

a) Piles should if possible be tested at the cut-off level and trimmed to sound concrete. Any weak, broken concrete that sounds hollow should be removed and the pile top left roughly horizontal over the complete cross section.

b) Reinforcing bars should be bent slightly away if practicable and the helical removed to allow for a good swing of the test hammer.

c) Two areas should be prepared for the transducers, one for the hammer in the centre of the pile and the other for the geophone close to the pile perimeter. The areas should be approximately 100 mm in diameter and prepared as flat and level as possible using a scabbler, scutch hammer or a hammer and chisel, then brushed free of debris with a wire brush. If at first you are unable to obtain a valid result, it is always advisable to re-prepare the pile and carry out a re-test, as cracking in the pile head is not always apparent but can affect the test result significantly.



Simulation of Pile Shaft Overbreak

Simulation of test results

The Simulation software is a finite element programme that simulates the frequency response of a real concrete pile by defining it and the surrounding soil in up to 10 segments. For each segment, the following information can be input: length, diameter, concrete wave propagation velocity, concrete density, soil shear wave velocity, soil density and base soil details.

With the TPAP simulation it is possible to super impose the simulated result onto a real frequency response curve. Soil and Concrete parameters can be changed using sliders and the simulation alters instantaneously in response.

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Testconsult Ireland Ltd
Materials Laboratory, Clonminam Ind Est
Portlaoise, Co Laois, Ireland
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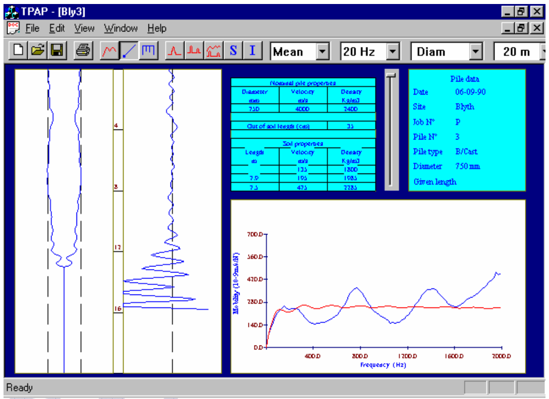
The operator is able to carry out curve matching to simulate the probable cause of any anomalies. Simulations are generally carried out on pile test results that have shown an intermediate response and enables a high degree of confidence in the interpretation.

Impedance Profiling

The impedance profile method of analysing pile integrity results combines the mobility curve obtained at the top of the pile and details of soils surrounding the pile to produce a specific reflectogram of the pile shaft, and a profile of the variation of local characteristic impedance, as a function of depth. The local impedance is well related to the mechanical properties of the concrete cross-section.

To create an impedance profile, the nominal pile concrete properties and dimensions are input, together with the known soil conditions. The resulting impedance profile enables the operator to check for reductions in pile impedance, which could be caused by bands of poor quality concrete, of necking and increases in pile impedance, probably caused by increases in pile section, or overbreak.



Impedance profile of shaft necking

Tdr Test Accuracy

Error calculations for TDR test responses are highly complex, due to the many factors involved. The accuracy of response curves is influenced by equipment accuracy and operator accuracy. As a guide, the accuracy of mobility and frequency measurements are shown in the table below for a standard test with black hammer tip to 1000Hz:

Frequency Range	Mobility Accuracy	Frequency Accuracy
0 – 20 Hz	Very low	± 0.5%
20 – 800 Hz	± 15%	± 0.5%
800 – 1000 Hz	± 50%	± 0.5%

Background vibration on site can also influence the accuracy of results. This is however usually apparent to the site operator, who can take the necessary action to remove the source.

Pile head preparation is the single most important factor which influences test results.

A poorly prepared pile will not inhibit the accuracy of the result – it will not, however, properly represent the body of the pile.

TDR PIT Testing performed by Testconsult Limited in the UK and Testconsult Ireland in the Republic of Ireland is carried out under UKAS accreditation. Testconsult was the first company in both countries to obtain this independent certificate of quality for pile integrity testing. Both companies are accredited against ISO17025, which covers both management and quality systems. Full details of our accreditation can be obtained direct from the UKAS website at www.ukas.org.uk

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Tdr Test Limitations

One of the most apparent limitations of the TDR test is the depth to which the method can prove pile continuity or assess shaft anomalies. On very long piles with a length/diameter ration, say, in excess of 30:1, the toe response is usually either very faint or not visible. Where a toe response is not visible it is not possible to infer shaft continuity. The same applies to shaft irregularities, in that the deeper they are the more difficult they are to detect and assess.

Apparent changes in shaft section of less than 10% will generally not be detected. In the case of multiple shaft irregularities, the test is usually only able to locate the first, although in the case of closed, horizontal cracks near the pile top it is sometimes possible to detect continuity below the crack.

It is often difficult to separate apparent necking, i.e. a change from an oversize upper section to nominal diameter, from a genuine reduction in diameter.

Crack detected at 3.5m using TDR

Checking tower leg foundations at remote stations in New Zealand using the TDR2

The interpretation of results relies heavily on supplementary data such as geotechnical conditions, construction technique, pile geometry etc. Our interpretation is given in good faith and assumes that no relevant information has been withheld from us. Such testing is an indirect method of assessing shaft integrity and should not be the sole criteria of pile acceptance and should not be construed as a piling guarantee.

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