



TEST REPORT

No. 50979/1

Dynamic Testing of Piles
by the
SIMBAT Method

Site: Chorlton Villas, Chorlton-cum-Hardy,
Manchester, M21 8DN

Job No.: PN50979

Visit No.: 1

Prepared for: **Hughes & Hilton Piling Limited**
Date typed: 30th | August 2021

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1. INTRODUCTION

James Fisher Testing Services Ltd (JFTS) were instructed by Hughes & Hilton Piling Limited to carry out SIMBAT dynamic load testing of 1 pile on their site at Chorlton Villas, Chorlton-cum-Hardy, Manchester, M21 8DN.

The purpose of testing was to determine the static behaviour of the pile up to 2.6 x working load.

Testing was carried out on 25th August 2021 and this report presents the test results, our interpretation and conclusions.

2. SITE DESCRIPTION AND PILE TYPE

The pile and associated groundworks will form the foundations for a new development on the site.

The pile tested was nominally 150 mm in diameter, approximately 10.0 m in length, and of the bottom driven tubular steel type.

3. METHODOLOGY

The SIMBAT technique is fully described in the literature included in the Appendix. It consists of the following steps:

- Instrumentation of the pile top with two strain gauges, two accelerometers and a theodolite target.
- Dropping a mass (in this case 400 kg) on to the pile top and recording strain, acceleration and displacement for each blow.
- Pre-treatment of the acceleration and displacement signals to verify the integration constant, thus establishing corrected velocity.
- Decomposition of the signals into upward and downward forces and calculation of the dynamic soil reaction for each blow.
- Plotting dynamic soil reaction with pile penetration, blow by blow.
- Correction of the dynamic loads into static loads.

- Calculation of the elastic shaft compressibility from the integral of force and the integral of displacement.
- The predicted static load test curve is then obtained by adding the elastic compressibility to the cumulative pile penetration.

All data was stored for subsequent signal processing.

4. SIGNAL PROCESSING

Before the dynamic reaction can be measured it is necessary to convert strain to force using the multiplier, K_f .

$$K_f \times \text{Strain} = \text{Force}$$

The multiplier, K_f = dynamic modulus of the pile head $\times$ cross section. We have used a value of 0.95 kN/ μ strain in this analysis.

It is also necessary to calculate the pile impedance, Z = density $\times$ propagation velocity $\times$ cross-section. We have assumed:

	CONCRETE	STEEL
Density	= 2,400 kg/m ³	7,800 kg/m ³
Velocity	= 4,000 m/s	5,200 m/s

Therefore $Z = 219 \text{ kN/m/s}$

Using these values, force separation diagrams have been produced for each blow and an example of these is included in Appendix 1. This diagram shows 5 separate traces:

- 1 Total force.
- 2 Downward force $\downarrow F$
- 3 Characteristic impedance ZcV .
- 4 Upward force $\uparrow F$.
- 5 Upward force in free pile.

The dynamic soil reaction is obtained by deducting 4 from 5 where 5 is at a maximum.

Also enclosed in the Appendix is a plot showing how the corrected velocity is obtained using the theodolite measurement as a base.

5. **TEST RESULTS**

The pile was subjected to a number of blows, all of which have been used in the analysis phase.

The blow No., drop height, penetration and dynamic soil reaction are recorded in Table 1.

Elastic shaft compression are estimated to be approximately 10.65 mm/MN and this value has been added to the final plot.

6. **CONCLUSION**

The SIMBAT dynamic load test has been able to predict the static behaviour of the pile as follows:

Pile Number : P16

Settlement at working load of 130 kN = 1.4 mm

Settlement at 1.5 x working load = 4.3 mm

The pile tested performed adequately under the applied loads and are therefore considered to be satisfactory.



IWAN JONES

Technical Authority Foundations

For and on behalf of JFTS

SIMBAT DATA SHEET

Site name **Chorlton**
 Date **25/08/2021**
 Pile No **16**

Job No. **P 50979**
 Operator **IJ**
 Pile type **Driven Steel**

Pile Head

Outer Diameter (mm) **150**
 Casing wall thickness (mm) **3**
 No of Reinforcing bars **1**
 Rebar diameter (mm) **16**

Total pile length **10.0**
 Distance to gauges (m) **0.5**
 Pile length from gauges to toe **9.5**
 Theodolite distance (m) **3.30**

Main body of pile

Shaft Diameter (mm) **150**
 Casing wall thickness (mm) **3**

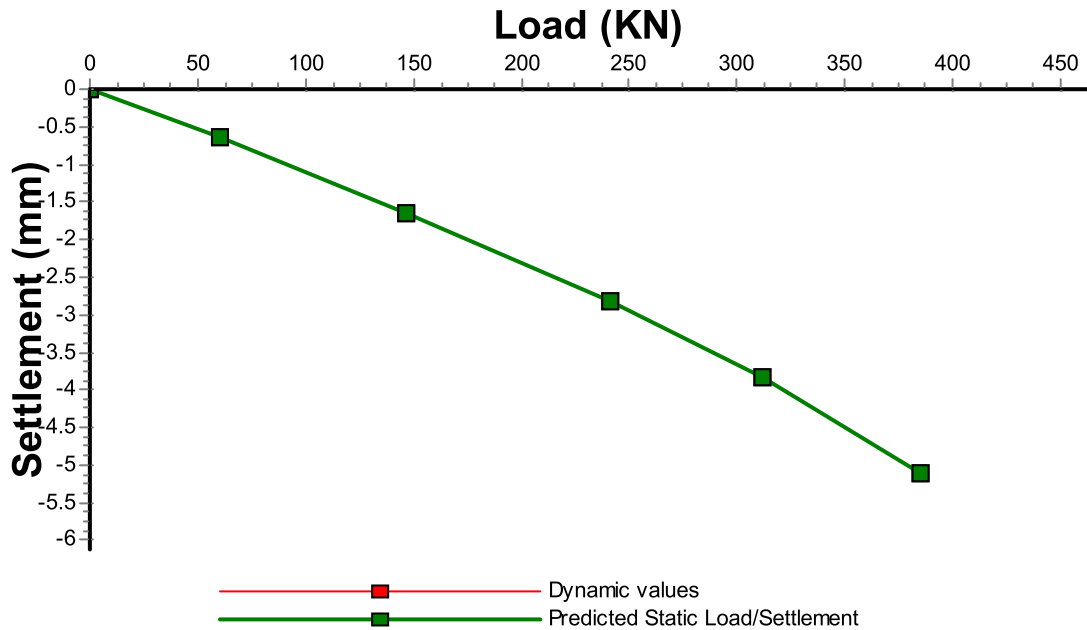
SSTAT from SIMBAT 10.65
SSTAT from TDR
SSTAT used for static

Blow No	Drop ht (m)	File	Pen (mm)	Rdy (KN)	Remarks	Not used
1	0.2	CHO16_01.bb	0.00	60		
2	0.4	CHO16_02.bb	0.08	147		
3	0.6	CHO16_03.bb	0.17	241		
4	0.8	CHO16_04.bb	0.50	328		X
5	1.0	CHO16_05.bb	0.25	312		
6	1.2	CHO16_06.bb	0.50	385		

PREDICTED STATIC LOAD SETTLEMENT PLOT

Site name **Chorlton**
Date **25/08/2021**
Pile No **16**

Job No. **P 50979**
Operator **IJ**
Pile type **Driven Steel**



File Name **16.tbl**

Static Flexibility, SSTAT (mm/MN) **10.65**

Analysis:

Design Working Load, DWL (KN) **130**

Predicted settlement at DWL (mm) **1.4**

Predicted settlement at DWL x2.6 (mm) **4.3**

Maximum Dynamic Resistance (KN) **380**

K = **0**

Remarks:

Analysis carried out by: **IJ**

Signed

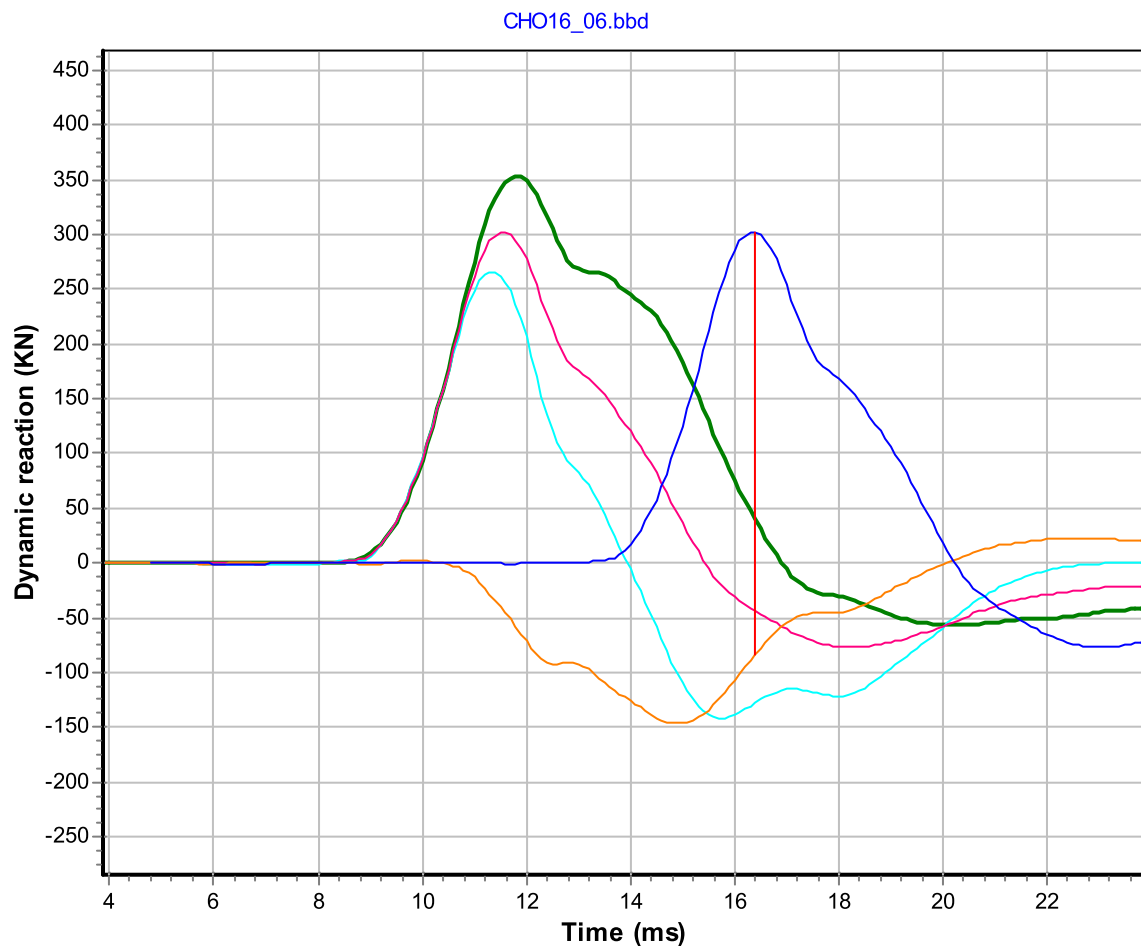
APPENDIX 1

**FORCE SEPARATION CURVE &
CORRECTION OF VELOCITY DATA**

FORCE SEPARATION SHEET

Site name **Chorlton**
Date **25/08/2021**
Pile No **16**

Job No. **P 50979**
Operator **IJ**
Pile type **Driven Steel**

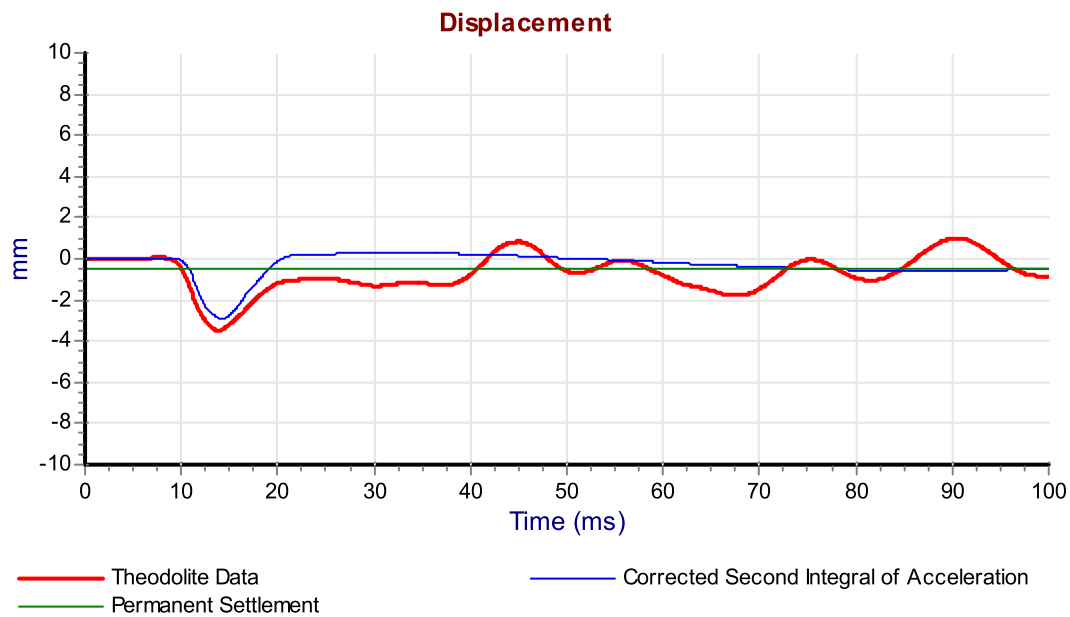
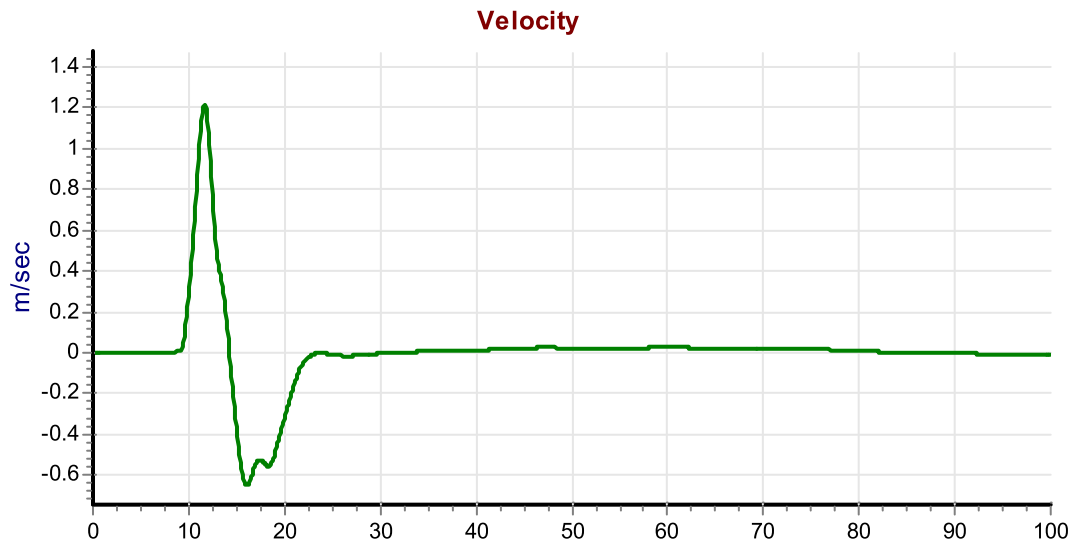


File name **CHO16_06.bbd**
Blow No. **6**
Drop Height (m) **1.2**
Rdy (kN) **385**

— Total force
— Downward force ↓ F
— Characteristic impedance Z_{cV}
— Upward force ↑ F
— Upward force in free pile

DISPLACEMENT / VELOCITY CORRECTION

File name **CHO16_06.bbd**



APPENDIX 2
SIMBAT BROCHURE

FOUNDATION TESTING DATA SHEET 3

SIMBAT – Dynamic Load Testing

James Fisher
Testing Services

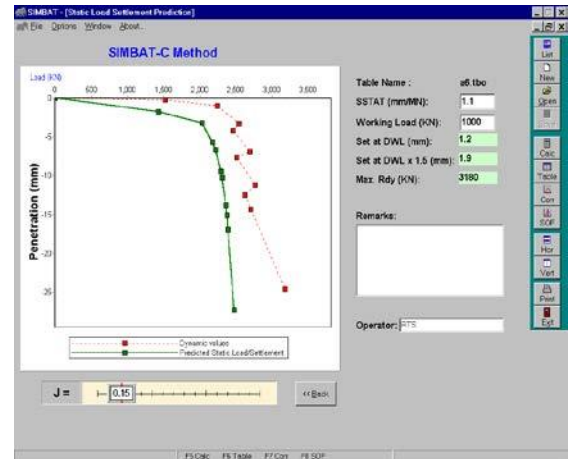


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James Fisher Testing Services Ltd has been offering a dynamic pile test service for many years using the SIMBAT technique. The technique is a dynamic pile test that allows the prediction of static load settlement behaviour of bored, cast-in-place and pre-cast driven piles. It is recognised by many organisations as being a superior alternative to other systems, as it includes a number of features that enables the operator to validate data, such as the specially designed optical theodolite.

Recent trials carried out in Belgium have proven that the system can produce good correlations with static load test results, even better than some 'quasi-static' dynamic test systems.

The prime advantages of dynamic load testing is the speed of testing and low cost. Typically, anything up to 10 piles per day can be tested and preliminary results can be available on the same day. The rate will depend on preparation and the type of drop weight used.



SIMBAT Load – Settlement Plot

Principle of the Test

The method is based on the propagation of waves in long elastic cylinders. When the pile top is struck with the falling weight the pile section is deformed (enlarged) and this enlargement travels down the pile to the toe where it is reflected back up. In a free, un-damped pile the particle velocity of the return wave would be identical to the original wave.

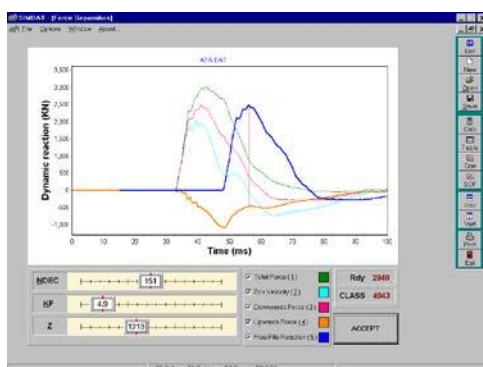
When the pile is surrounded and restrained by soil, part of the wave is reflected back up at each and every external restraint, the remainder of the wave continues downwards. So at any one time there are both upwards and downwards forces and velocities in the pile.

The SIMBAT technique is able to separate these upwards and downwards forces, F (up) and F (down) and calculate dynamic soil reaction, Rdy, as the difference between the upwards force in a free pile and the real upwards force measured. The conversion of dynamic to static reaction is carried out by expressing Rdy as:

$$Rdy = R_{STAT} + (K \cdot ep)a$$

Where: ep = permanent penetration. K = a parameter which is a function of the pile and the sequence of the blow. a = a parameter which is a function of the soil.

An integral part of the procedure is a numerical simulation whereby experimental signals are introduced into the programme and compared with theoretically generated signals. This pile/soil model enables the distribution of soil resistance down the shaft and at the pile toe to be determined.



Separation of Forces

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FOUNDATION TESTING DATA SHEET 3

SIMBAT – Dynamic Load Testing

James Fisher
Testing Services



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METHODOLOGY

The first stage of the test is to build a pile cap, 2.5 x the pile diameter in height and reinforced sufficiently to prevent bursting under the drop weight impact. Normally it is sufficient to use a thin wall steel casing. It must have a smooth surface and constructed of good quality homogeneous concrete as it is effectively acting as a dynamometer.

Strain gauges, accelerometers and a special theodolite target are mounted on the side of the cap. These are all connected to the portable SIMBAT data acquisition system.

A laser guided high speed optical theodolite is set up between 3-5m from the pile and pointed at the target. This can measure the displacement of the pile cap, before the surface wave reaches it, totally remotely from the pile.

A cushion of rope is placed on the pile to ensure an even distribution of load, prevent tensile cracking and to increase the duration of the test blow.

A series of impacts are made with the hammer drop height being progressively increased/ decreased in magnitude. This applies high and low strains to the pile and is a crucial part of the SIMBAT methodology.

All data, i.e. acceleration, strain and displacement, are stored during the test and can be analysed immediately if required. This data is then processed to give the dynamic reaction of the pile, which is corrected to give the equivalent static reaction of the pile.

The drop weight required will depend on the test load and the mass of the pile. As a guide, the drop weight mass will generally be 1% of the test load or 10% of the pile mass – whichever is greater. It is not recommended to use a smaller drop weight with a bigger drop height, as this can produce high tensile forces in the pile, which can lead to cracking.



SIMBAT Theodolite



30,000KN Simbat test in Taiwan

There is no real limit to the test load that can be applied, the largest test to-date being 30,000KN, carried out using a 30T drop weight in Taiwan, and the smallest being 50KN carried out using a 200Kg drop weight.

On overseas contracts, or where transport is a problem, drop weights can be constructed locally using concrete or steel, and we can provide guidance on the most suitable type of weight to use and supply quick release systems to ensure a free-fall drop.

In the UK we also provide a service to test mini piles, using a small hand portable half tonne drop weight system. The unit can be dismantled for use in buildings and difficult locations or on trackside contracts.



Minirig Simbat Testing

James Fisher Testing Services Limited

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APPENDIX 3

**SIMBAT - A DYNAMIC LOAD TEST FOR BORED PILES
- STAIN AND FRENCH**

SIMBAT

-A DYNAMIC LOAD TEST FOR BORED PILES

Authors:

*R T Stain & S French
TESTCONSULT LIMITED*

PILING EUROPE

London, 7-9 April 1992

Dynamic load tests for piles have been available for several years and are in quite common use throughout the world. The object of these tests is to predict the Static behaviour of a pile from Dynamic measurements. The tests are marketed under what are essentially trade names (or the names of the computer programs). The latest method to be introduced is known as SIMBAT and was developed by the CEBTP in France.

There has developed around these methods, and SIMBAT in particular, an aura of mystery which to a large extent has been created by the practitioners themselves. Very few end users would admit to a full understanding of either how the methods work or what their limitations are. This paper aims to clarify the procedures involved in the SIMBAT technique and to indicate the limitations and typical accuracy of the method.

The paper is in four parts:

- Theoretical Principles - Practical Considerations
- Analysis of Results - Typical Dynamic/Static correlations

THEORETICAL PRINCIPLES

1. A dynamic load test consists essentially of dropping a mass onto the top of a pile and measuring the pile top movement and force. The data obtained is then processed and manipulated to predict the behaviour of the pile under static loading. If only it were that simple!

2. The following section tries to clarify the principles of dynamic testing diagrammatically using a step by step approach. Formulae have been excluded.

Waves in a pile

3. When a mass is dropped onto a pile it compresses the concrete immediately under the mass. This compression is transmitted to the next layer of concrete and so on, the net effect being a compression 'wave' which travels down the shaft. When this wave reaches the base of the pile it is reflected back up again until it reaches the pile top. The time taken for this return journey is very small, in the order of a few milliseconds, but it is nonetheless finite and measurable. If the pile length (l) and the wave speed (C) are known, then the return time can be easily calculated.

4. It is interesting to examine the effect of dropping a mass onto two theoretical piles, the first having no soil support either along the shaft or at the base and the second being supported only at the base by an infinitely rigid material.

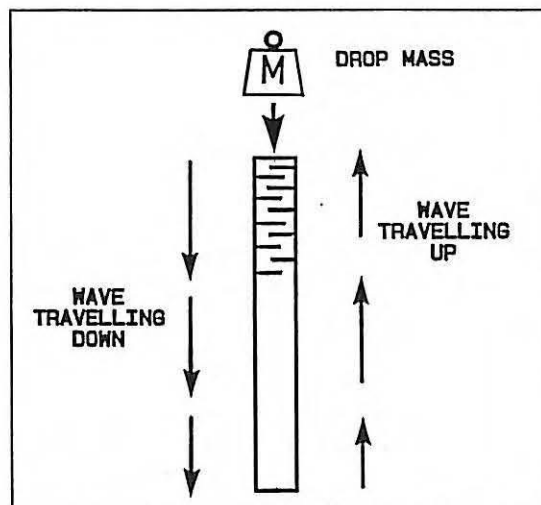


FIG.1 Wave Propagation in Concrete Pile

Pile top velocity

5. In the first case, when the pile is struck the compression wave travels down the shaft to the base in the normal way. As each succeeding layer is compressed it creates a minute bulge in the shaft as it goes, rather like a snake swallowing an egg.

6. The reflected wave, which travels up the shaft is not however quite the same, it is no longer a compression wave but a tension wave as shown in Figure 2. If the movement of the pile is monitored throughout this cycle using a velocity transducer both the initial impact and the reflected wave will appear identical, separated only by the travel time. This is because the downward compression wave causes the pile top to move down and the upward tension wave causes an identical downwards movement.

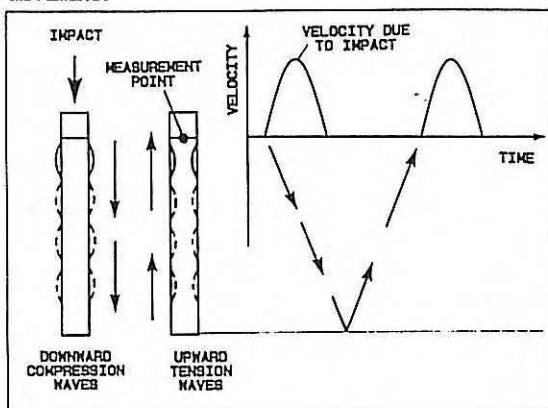


FIG.2 Wave Travel in Free Pile

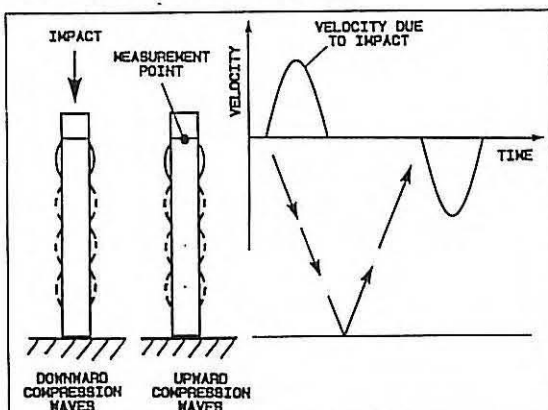


FIG.3 Wave Travel in Pile with Rigid Base Support

7. In the second case when the pile is resting on a rigid base the upward wave from the pile base is a compression wave which, of course, causes the pile top to move up and not down as in the previous case. The effect of this can often be seen during pile driving operations. The hammer hits the pile top and a split second later the hammer suddenly rebounds as the return wave arrives.

8. When a pile is surrounded by soil, each layer of soil causes a restraint so that as the compression wave from the hammer blow travels down the shaft, part of it is reflected back up from each and every restraint and part of it carries on down. The reflected wave from a

soil restraint is a compression wave, just like the return wave was in Figure 3 from the pile toe.

9. What does this do to the velocity that is being measured near the pile top? The net effect is that it decreases it - the mass is trying to push the pile top down while the return wave is trying to push it back up again and the two partially cancel each other out. An example of return waves from a pile with a single layer soil restraint is shown in Figure 4. A more realistic velocity trace from a pile with continuous soil restraints is given in Figure 5.

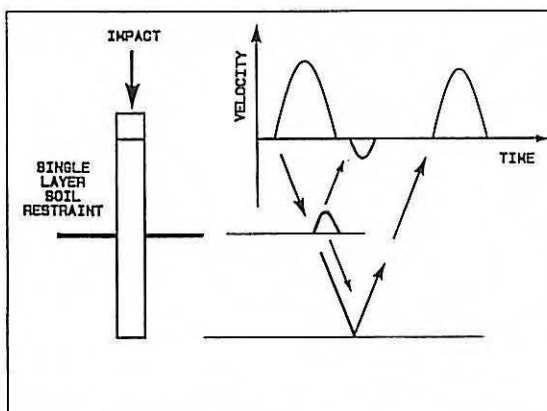


FIG.4 Velocity Response from Pile with Single Layer Soil Restraint

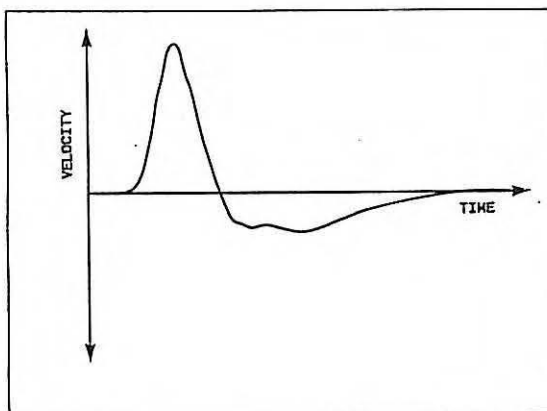


FIG.5 Velocity Response from Pile with Continuous Soil Restraints

10. It should be pointed out that traditionally, downward velocities are shown as being positive and this has been adhered to in this paper. When the pile top moves down the velocity is positive.

11. This is one of the single most important principles of dynamic testing - SOIL RESTRAINTS CAUSE UPWARD VELOCITIES (AND FORCES), and it is these that we are trying to quantify.

Forces in the pile

12. So far, only the pile top velocity has been considered and on its own this is not much help in determining the reaction to load. It will be apparent however that force and velocity are proportional to each other, indeed they are both caused by the same impact on the shaft. (Ref 1, P Hannigan 1988) The force and velocity signals can in fact be made equal by multiplying the velocity by a term known as the pile IMPEDANCE, traditionally represented by Z .

$$\text{Therefore } \frac{\text{VELOCITY} = \text{FORCE} / \text{IMPEDANCE}}{\text{FORCE} = \text{VELOCITY} \times \text{IMPEDANCE}}$$

13. This relationship is only true when there are no soil restraints on the pile, which as we have seen have a decreasing effect on the velocity.

14. What happens to the force near the top of the pile when soil restraints are present? Unlike the velocity, which is diminished by the upward waves, the force is increased. This is a bit like two cars colliding head on - their resultant speed or velocity is zero but the force of the impact is double what it would have been had a single car collided with a wall.

15. SOIL RESTRAINTS ON THE SHAFT CAUSE AN INCREASE IN FORCE AND A DECREASE IN VELOCITY at a point close to the pile head where the measurements are always made.

Soil Reaction

16. It is now possible to produce a double plot of both force (F) and velocity $\times$ impedance (ZV) for a real pile, as shown in Figure 6.

17. The shaded area, or difference between the two plots, is purely due to restraints acting on the shaft. Note that in this example the toe response is very weak due to the damping effect of the lateral soils.

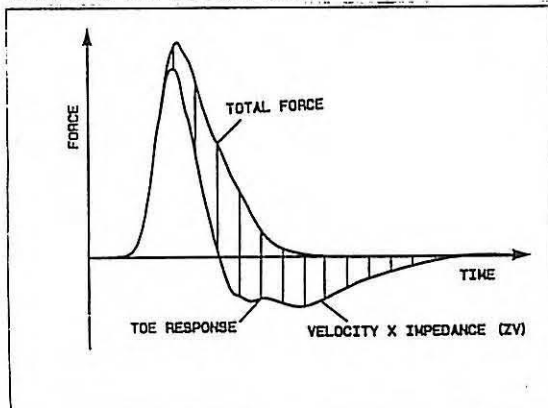


FIG.6 Diagram Showing Total Force and ZV

18. The force shown is, of course, the total force, that is the combined effect of the downward force, $F_{\downarrow}$, and the upward force, $F_{\uparrow}$. It is apparent that had there been no upward forces (or soil restraints) then the downward force, $F_{\downarrow}$, would lie midway between these two

lines - see Figure 7. Also since the total force is the sum of $F_{\uparrow}$ and $F_{\downarrow}$, then the upward force must be the total force minus the downward force.

$$\text{UPWARD FORCE} = \text{TOTAL FORCE} - \text{DOWNWARD FORCE}$$

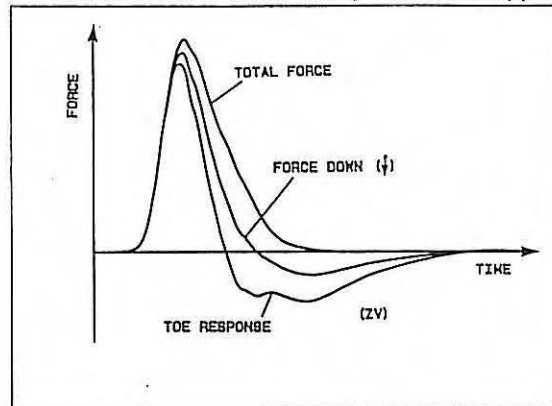


FIG.7 Diagram Showing Downward Force

19. This upward force has been superimposed and is shown in Figure 8.

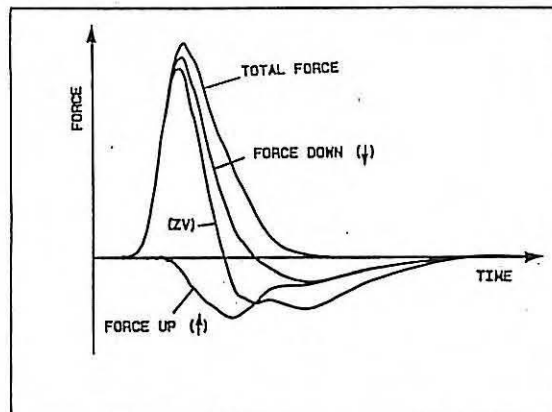


FIG.8 Diagram Showing Upward Force

20. Finally, had there been no soil restraints, the $F_{\uparrow}$ would be equal to the $F_{\downarrow}$, but shifted to the right by the time taken for the return journey. We can now, at last, measure the soil reaction forces due to the particular hammer blow. This is shown in Figure 9.

21. THE SOIL REACTION IS THE DIFFERENCE BETWEEN THE UPWARD FORCE IN A FREE PILE AND THE ACTUAL UPWARD FORCE MEASURED.

22. This is the principle of all dynamic pile test systems and remains unchanged since the original CASE formula was developed in 1972. (Ref 2, Rausche et al).

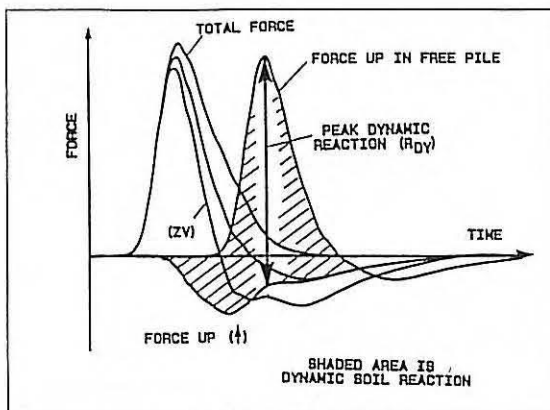


FIG.9 Diagram Showing Dynamic Reaction

Ultimate reaction

23. In many applications the object of the dynamic test is to measure the ultimate capacity of the pile. This cannot, of course, be measured with a small hammer blow as the upward reaction will never exceed the downward force applied. How large then must the hammer blow be to mobilise all the possible reaction forces? - The answer is that we don't know.

24. It is clear, however, that it is not possible to measure the ultimate reaction without moving the pile sufficiently for all of the soil layers to have reached their maximum or limit reaction. It seems to be a widely held belief that it is somehow possible to predict the ultimate capacity without actually penetrating the pile by more than a millimetre or two. This is not true. Just as in a static load test, the pile must penetrate considerably for the peak forces to be obtained and measured.

25. It would be quite easy to see if each separate soil layer had reached its ultimate if we were able to attach instruments all the way down the shaft. In this way, the reaction from each layer could be examined. If the reaction were 'flat topped' as in Figure 10, then clearly that layer would have reached its ultimate.

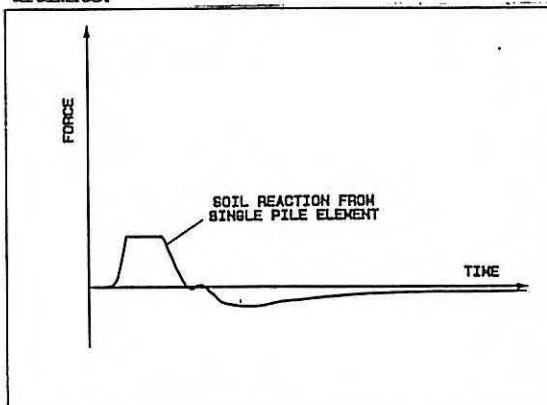


FIG.10 Soil Reaction from Single Pile Element

If all soil layers including the toe had the same effect then we could be sure the reaction measured was the ultimate. Or could we?

26. For this to be true they would all have to be 'flat topped' simultaneously or at least hold this condition long enough for them to cumulate properly when measured near the pile top.

27. Unfortunately it is rarely feasible to instrument the pile in this way and it would certainly be uneconomical for routine testing.

28. The only way to tackle this problem is by simulation, that is by creating a realistic pile/soil computer model. A single element of the SIMBAT model is shown in Figure 11. The concrete and soil parameters are then adjusted, layer by layer and the model is subjected to the same impact as the pile. The response from the model is plotted. These parameters are progressively adjusted until the simulated responses (velocity and displacement) match the measured ones.

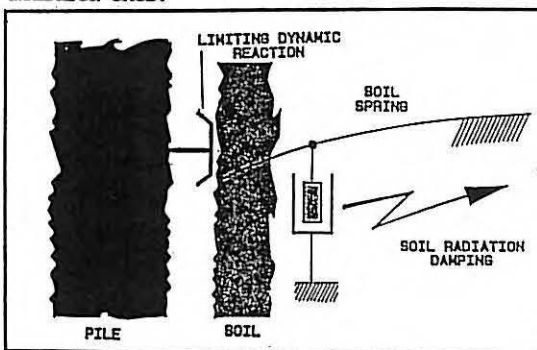


FIG.11 SIMBAT Simulation Model

29. It is then considered that the soil parameters are correct and at this stage the upward forces from the model can be examined layer by layer to see:

- a) if they have all attained rupture or limiting reaction, and
- b) if the cumulative reaction force is equal to the sum of the individual limit reactions.

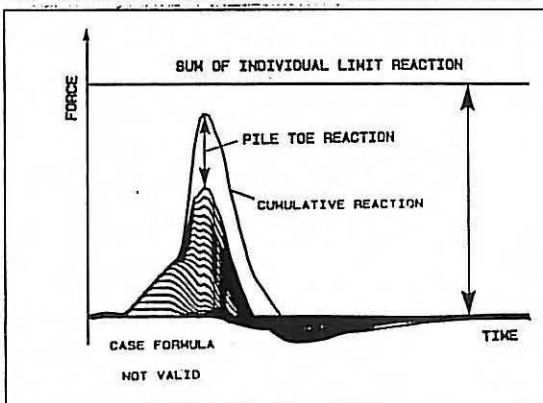


FIG.12 Verification of CASE Formula

30. These are not the real layer by layer forces which we cannot measure, but the simulated ones.

31. This verification procedure is essential and is one that is often ignored. An example of such an exercise is shown in Figure 12.

Dynamic to Static conversion

32. Suppose that a certain pile in clay has an ultimate static capacity of 4000 KN. The reaction of the same pile under dynamic loading would, however, be considerably higher, possibly by a factor of 2, so that the dynamic reaction could be 8000 KN. This is because of the time-dependent visco-elastic nature that most soils exhibit. The faster the strain rate, the bigger the soil reaction will be.

33. This effect is apparent even at relatively slow strain rates - a constant rate of penetration test (CRP) on a pile will produce a higher ultimate capacity than a maintained load test.

34. It is now necessary to find a method of correcting the dynamic reaction to a static value and there are several approaches.

35. The first method, and that used by the early workers in this field, was to establish a large database of correlations based on real results, dynamic and static tests being carried out on the same piles. In this way, soil 'damping' factors slowly evolved for different soil types. The soil damping factor (J) ranged from just over 1 for highly cohesive clays to less than 0.1 for non-cohesive sands and gravels. The static reaction was then calculated by firstly estimating an appropriate J factor based on a knowledge of the soil conditions. The measured (or dynamic) reaction was then reduced by an amount proportional to the J factor and the pile top velocity to give a static value. This method is still in use today and is an extremely rapid and useful indicator although the accuracy does depend on a correct assumption of J. The formula is given at the end of this paper.

36. Another more recent technique and one that avoids the necessity to assume a J factor was developed in 1987 and is part of the SIMBAT methodology. This requires that a large number, typically ten or more, separate hammer blows are applied to the pile and the dynamic reaction measured for each one of them. The impacts are arranged so that a wide range of soil strain rates are achieved. All are high strain rates of course, in comparison to static loading, but nonetheless some of the blows achieve higher strain rates than others. In practice, this is easily achieved simply by varying the drop height of the mass. Figure 13 shows the principle of the operation.

37. By projecting the dynamic measurements back to a zero strain rate or zero penetration velocity the static reaction is obtained. In fact, the projection is not necessarily a straight line as shown in Figure 13, but may follow a power law as given by Heritier Ref 3.

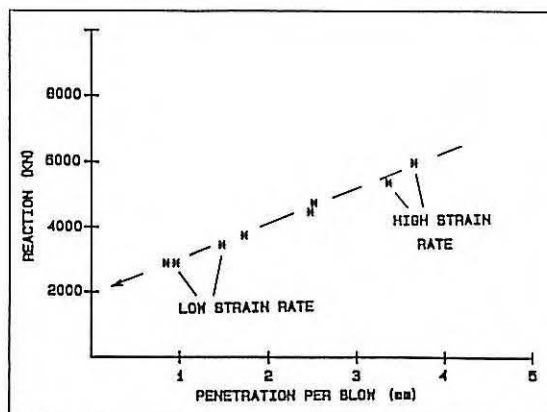


FIG.13 Dynamic Testing at Varying Strain Rates

38. One of the great advantages of this method is that, coupled with the accurate measurement of pile top displacement for each blow, a complete load/settlement plot can be produced. It also avoids, as mentioned previously, the need to assume a soil damping factor which may or may not be appropriate for the particular soils. The technique is different to the previously mentioned one in that pile penetration velocity is used as an adjuster and not pile top velocity - these two values are quite different. Finally it also avoids the need to refer to the 'ultimate' capacity of the pile, a quantity which has been defined in many different ways and is not necessarily the true sum of all the soil reactions.

39. An example of this correction procedure is given in Figure 14.

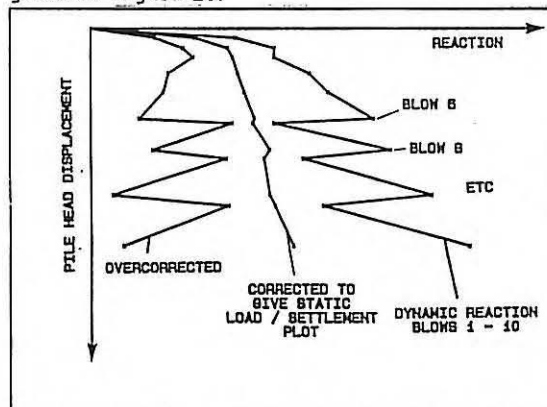


FIG.14 SIMBAT Dynamic to Static Correction Procedure

PRACTICAL CONSIDERATIONS

Instrumentation

40. To measure the force and velocity waves the pile is instrumented with accelerometers and strain gauges.

41. The choice of these instruments is extremely important. From experience it has been found that foil strain gauges perform consistently well under the high acceleration

encountered during testing. This is because the foil strain gauges are virtually massless and therefore immune to inertia effects. Foil strain gauges can only be used once and therefore always conform to manufacturers' calibration and specification.

42. The accelerometers used are of the PCB 305A04 type which are suitable for high levels of acceleration encountered. The mounting block assembly is extremely critical and is designed so that the resonant frequency and the degree of damping are as high as possible.

43. The SIMBAT system differs from other generic dynamic pile testing systems by using an electronic scanning theodolite. The theodolite performs two useful functions, firstly to record penetration for each blow and secondly to record real time elastic displacement.

44. The elastic displacement is of particular interest as it is used as a base for acceleration data correction.

45. All instruments are attached to the pile approximately 2.5 diameters from the top (see Figure 15).

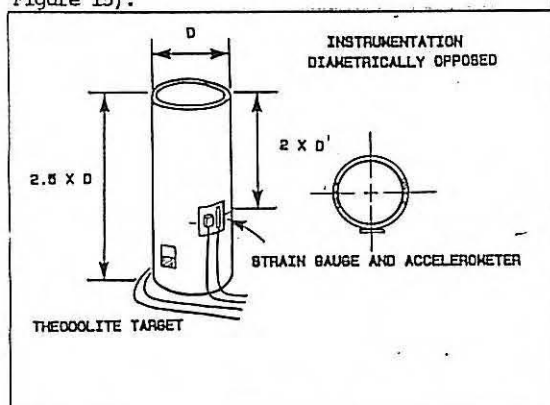


FIG.15 Location of Instruments on Pile

Choice of Measuring Section

46. The measuring section or point at which the instruments are attached must be regular and in this respect it has been found most advantageous to cast a pile cap of the same diameter as the pile using thin section steel casing. The distance from the pile top to the measuring section is determined by reference to the following criteria:

- 1 - so that the pile can act as a dynamometer
- 2 - so that the generated stresses become uniform over the section,
- 3 - so that there is a small time before the upward wave from the first soil layer arrives.

47. The usual height of the pile cap is therefore 2.5 pile diameters with instruments arranged approximately 2 diameters from the pile top.

Drop mass and cushion

48. A drop weight of sufficient mass to mobilise the pile is used to generate the input force.

49. A cushion is placed on top of the pile cap both to protect the concrete and to condition the duration of the impact. In practice a coiled nylon rope cushion has been found to be most suitable.

Drop height

50. The height of drop of the falling mass is progressively increased until a small permanent penetration is recorded. The drop height is then successively increased/decreased to achieve differing strain rates as described earlier.

51. For a full load settlement plot, typically 10-15 blows are required.

Acquisition of data

52. Strain gauges, accelerometers and the theodolite are connected via cable to an acquisition unit. The unit acts as a preamplifier and filtering module and is, in turn, connected to a PC with an internal analogue to digital card. Data is viewed on screen during the test and stored on hard disk for subsequent processing.

53. Typical raw data is shown in Figure 16.

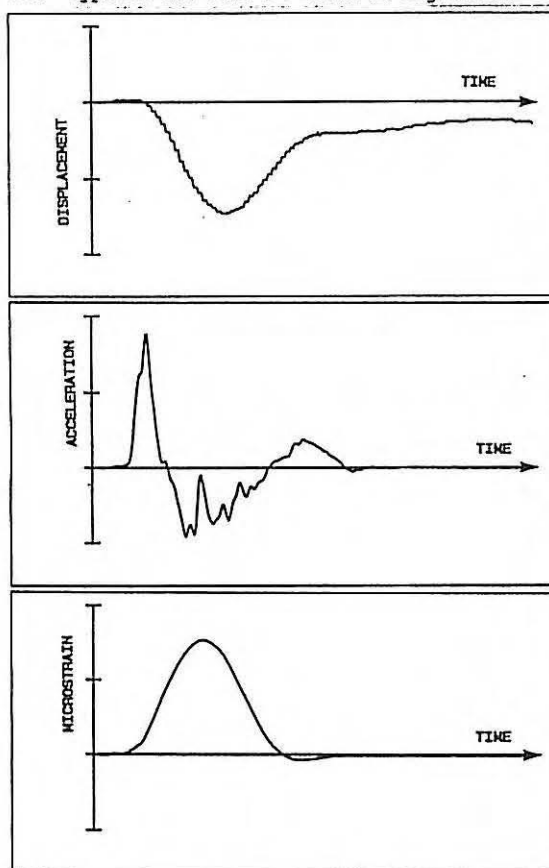


FIG.16 Raw Data from Single Impact

ANALYSIS OF RESULTS

Velocity Correction

54. Velocity is not measured directly but derived from the integral of the acceleration. To confirm the quality of this data the acceleration is integrated twice and compared with displacement data from the theodolite. Corrections can be made by applying either parabolic or linear functions (see Figure 17).

55. The verification of data by two independent measuring systems is most important and one that is often neglected.

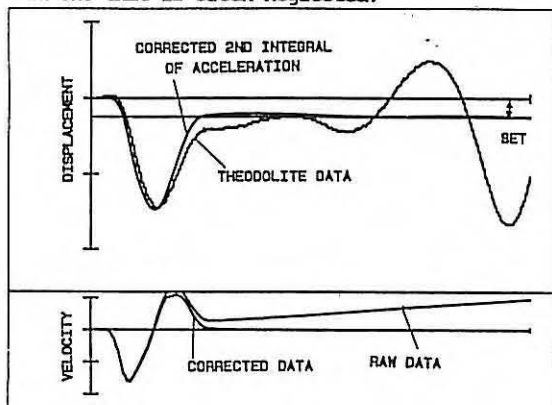


FIG.17 Correction of Velocity Using Theodolite Data

Separation of forces

56. The first stage of the analysis, which is often carried out on site, is to determine the dynamic soil reaction for each blow using classical principles.

57. A complete separation of forces diagram is shown in Figure 9. This procedure is undertaken on all blows, and tabulated together with the permanent penetration for each blow.

Simulation

58. There are two reasons for carrying out computer simulations:

- to verify that the dynamic reaction calculated using classical Case principles is equal to the sum of the individual limit reaction.
- to determine the distribution of soil resistances along the shaft and at the pile toe.

59. The SIMBAT model was described earlier in Section 1. Essentially the procedure consists of splitting the pile into 13 discrete elements, and assigning soil and pile parameters for each of these elements. The soil properties are entered as elastic and viscous components and the ultimate or limit reaction. These parameters are then adjusted until the model responds in the same way as the pile, both in terms of velocity and displacement (see Figures 18 and 19).

60. If the Case principles are shown to be applicable for each blow, then the dynamic reactions previously determined can be accepted. If not, then the total reaction of the model must be used in the final stage of analysis.

61. The transition from dynamic to static reaction can now be performed as described in Section 1.

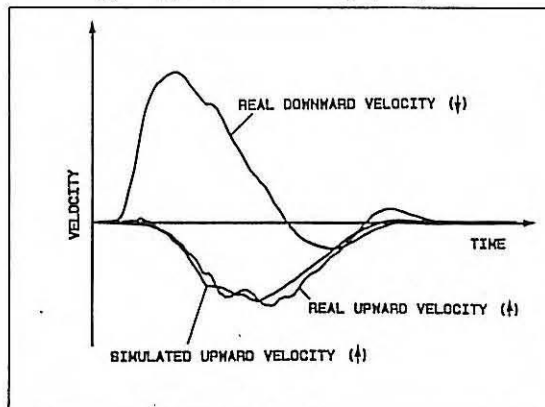


FIG.18 Computer Matching of Velocity

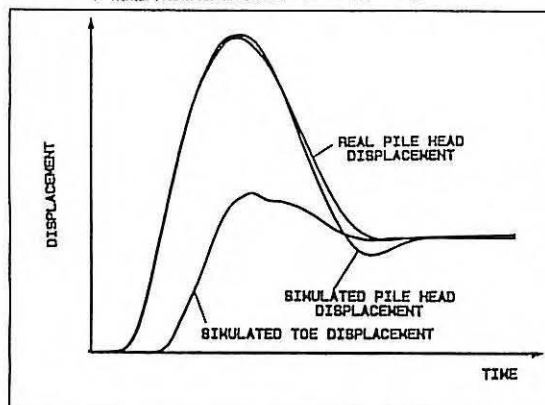


FIG.19 Computer Matching of Displacement

Calculation of elastic shaft compression

62. The results shown in Figure 14 are soil reactions plotted against toe penetration. It is therefore necessary to add to this plot elastic shaft compressibility. The most reliable and accurate method of determining this value is by direct use of the theodolite (displacement) and force measurements. It is not strictly accurate to simply divide the displacement by the force and instead the integrals of these two measurements are used. This shaft compressibility has been added to the toe penetration and a final static/load settlement plot is given in Figure 21.

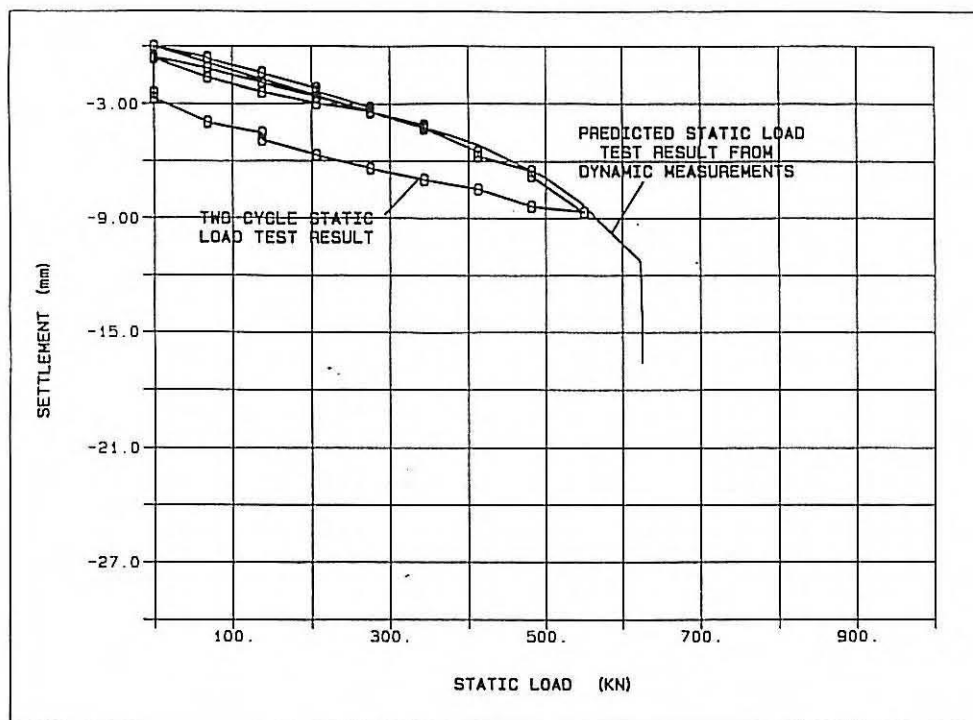


FIG.20 Comparison Between Static and Dynamic Load Tests

TYPICAL DYNAMIC/STATIC CORRELATIONS

64. A typical correlation between dynamic and static load test results is given in Figure 20.

FORMULAE

Case Method Capacity Prediction

$$R_{stat} = R_{dy} - J (ZV^1 + F_{TOT}^1) - R_{dy}$$

NOTE: Formula applied to a single discrete blow

SIMBAT Method Capacity Prediction

$$R_{stat} = R_{dy} - (K_{pen})^a$$

NOTE: Formula applied to complete series of blows

where: R_{dy} = total or dynamic reaction
 R_{stat} = static reaction
 J = Case damping factor
 Z = pile impedance
 V^1 = pile top velocity at time of impact
 F^1 = total force at time of impact
 pen = permanent penetration
 K = a parameter which is a function of the pile and the sequence of the blow
 a = a parameter which is a function of the soil

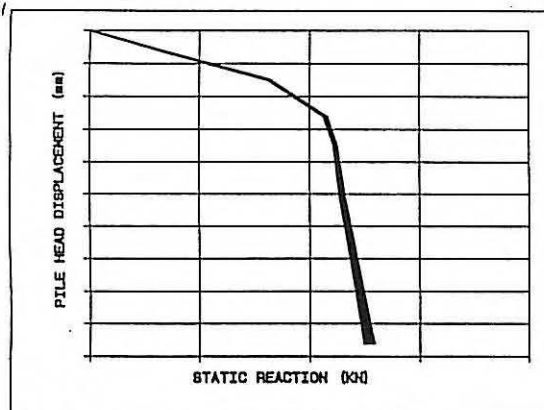


FIG.21 Final Static Load Settlement Plot

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 Ref 1 Rausche F., Moses F., and Goble G.G., 'Soil Resistance Predictions from Pile Dynamics', Journal of the Soil Mechanics and Foundations Division ASCE Vol. 98 No. SM9 Proc Paper 9220 September 1972.
 Ref 3 Heritier B, Paquet J, Dali B. Foundations Profondes - Paris, March 1991.