A Comparison between Static and Dynamic Load Tests on Bored Piles

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ABSTRACT
Piles are both statically and dynami cally tried to acquire the limit and to check outline. The two sorts will give comes about that may differ in light of the technique utilized as a part of leading the test. It is thusly, important to think about the aftereffects of a static load test with dynamic load test. Numerous comparison studies are directed around the world, yet the vast majority of them are for displacement driven pile. In this way, the consequences of the test are looked at for substitution-exhausted piles. The piles are tested statically before dynamic test. The test results show that a not too bad comprehension was expert between both the tests with in addition to less 7mm at design load regarding settlement. Moderately, the settlement foreseen in powerful load test is littler diverged from static load test. Regarding absolute bearing limit, Davisson's technique gives the insignificant outrageous load regard diverged from various strategies. The Davisson's strategy is utilized to analyze the outcomes since it is more moderate. The examination shows that the piles are inside 15% in regard as far as possible traversed Davisson's strategy. Since the static test was coordinated before unique test, the limit got from dynamic test is higher because of the pile experienced flexible pressure amid static load test and furthermore because of soil setup.
Keywords- Bored Piles, Static Load Test, And Dynamic Load Test

INTRODUCTION

Foundations are the important parts of a structure as they transfer load from the structure to the soils underneath them. These foundations can be subdivided into shallow or deep. Shallow foundations which are classified into footings, compound footings, and mat foundations are applied with shallow impact of the supporting soil. While, deep foundations such as piles and caissons are requested with tremendous impact of the supporting soil or at the point when structures are put on delicate compressible soil. pile foundation are additionally required if the headway is presented subjected to level load or moment.

Piles are predominantly gathered into two kinds; displacement and replacement piles. The first involve reinforced, pre-stressed, steel-H piles. While the second type, comprise of board piles, and cast in-situ piles. Each one of these piles is chosen to a specific circumstance of the site within the studied zone, ground condition, kind of the structure, and durability. Piles are laid out in perspective of the stresses that is transmit from the structure to the Piles ; thusly, the sort, size and length of Piles are settled as requirements .Notwithstanding, load test ought to be directed to check the plan limit. Piles that are not legitimately planned, would posture risk to the structure. Deficient load or substantial settlement would make serious harm the structure and its inhabitants. (Tomlinson, 2001.)

There are a couple of separating decisions to loadtest, i.e.: kept up stack test (MLT), HSD (Pile Driving Analysis), statnamic testing and Osterberg Cell stack test. These types of tests would equip the architect with the pile and the relating settlement. It genuinely empowers the architect in key activity as to continue with work or to take off moves up to the picked design criteria. of the four, the most sensible and the most for the most part saw as being entered in the business are the SLT and the High Strain Dynamic Test.

SLT (or kept up load test) is regularly known being developed industry. It utilizes water controlled jacking structure against a kentledge or against a pole confinement by get piles. The piles is measured by the investigating of stress gauge on the weight driven jack. At show, the pile is computed traightforwardly by a loadcell mediated between the jack and head of pile or between the jack and stage to get an exact and trustworthy estimation. This test is generally called ordinary

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test. It requires legitimate setup, labor, apparatus and longer term to keep up the pile (Fellenius, 2001).

HSDT test is guided utilizing 2 to 4 strategies of sensors known as accelerometers and transducers related with the pile. The explanation for this test is wave mechanics. The test needs sensors, pile driving analyzer and the pile driving structure. On each impact of the driving structure/crush, the sensors get the impact power and speed. The got indications of strain and expanding speed were adjusted and controlled by the PDA to make plots of energy and speed versus time. The capability to correctly foresee static farthest point concerning dynamic pile test has realized numerous examinations what's more, has been the concentrate of dynamic pile tests on many attempt ranges. Common practice needs performing transmission organizing on the data to more unequivocally choose restrain from the energetic testing. CAPWAP investigation is the best utilized software to assessment limit from HSDT information. Past investigations have exhibited by and large great relationship of CAPWAP flag coordinating outcomes on progressively re-strike tests with that of static load tests (Likins and Partners, 1996).

As, the implementation of the SLT and HSDT is quick for all intents and purposes coordinated in each site, examinations between the two tests for board pile is being tried in this study.

1. Problem Statement

There are numerous examinations coordinated on the comparison between the HSD testing and the approach CAPWAP technique, and SLT, yet the larger part of them were made for the evacuating piles. Through this investigation in any case, focus will be on substitution piles (exhausted piles). Examination is made between the SLT comes about and the approach CAPWAP flag coordinating outcome on powerful re-strike test. Moreover, an endeavor is made and prepared to look at the outcomes got from the keep up load test and the HSDT and CAPWAP examinations. The goal of leading this examination is to look at the outcomes got in the static load tests with that obtained by the high strain dynamic tests and CAPWAP investigation as far as: 1) The load and the corresponding settlement of the piles; and 2) The amount bearing mental ability of the pile.

High strain dynamic test

HSDT. is a compelling instrument to get the chance to pile driving, which may supplant static testing. This test is coordinated in a little measure of time dissimilar the SLT. This test relies upon the dynamic methodology for examination. Genuine field test is achieved on pile by measure strain and accelerating data under impact of a falling mass. The Wave condition examination program (WEAP) is used to plan the weight, drop stature and pad of the mallet contraption to guarantee a fruitful test. The pile driving analyzer and the CAPWAP strategies are utilized for information obtaining and examination. Testing comes about yield data with respect to pile static bearing limit, basic respectability, and pile soil load exchange and pile load development relationship.

HSDT. is driven using; two or three strain transducers or sensors mounted near the most astounding purpose of the pile, several accelerometers installed similarly near the most elevated purpose of the pile and the pile driving analyzer generally called PDA (piles driving analyzer) as showed up in Figure (1). The PDA screens the yield from the strain transducers and accelerometers as the pile is being built, and surveys the data as takes after:

1- The strain information consolidated with the flexibility modulus and cross segment zone of the pile, gives the hub constrain in the pile ;

2- The increasing speed information incorporated with time delivers the molecule speed of the waves going through the pile ;

3- The increasing speed information, twofold incorporated with time delivers the pile set per blow.

Utilizing the above information, the PDA figures the Case strategy limit and shows the outcomes instantly. Case method investigation is a systematic procedure for deciding the static pile limit

from wave follow information. The Case method calculations incorporate an experimental connection factor, **jc** that can be resolved from an on location pile load test.
It is likewise conceivable to utilize the Case technique without an on location pile load test by utilizing **jc** esteems from other comparable soils. This approach is less exact, yet at the same time exceptionally significant. The PDA can in like manner store the field data on a diskette hover to offer dedication to a CAPWAP test.
The Case method, while helpful, is a rearrangement of the genuine progression of pile driving. The exactly acquired damping factor, **jc** aligns the investigation, so the last outcomes are no superior to the specialist's capacity to choose the best possible esteem. Interestingly, a wave condition investigation uses a substantially more exact numerical model, however experiences powerless assessments of the real vitality conveyed by the sledge.
Luckily, the qualities and the shortcomings of these two systems are complimentary, so one can go along with them to shape an overhauled examination called CAPWAP (Case Pile Wave Investigation Program). It is an exhaustive numerical system for a sweeping examination of pile and soil lead under hammer impacts and moreover under static loading conditions. The examination is achieved in an iterative space using measured power and stimulating in a wave condition sort examination using signal organizing strategy that estimations of Ru (an authoritative resistance in the dirt 'springs'), q (the shiver), and jc (the Case procedure damping factor). CAPWAP tests are not a substitute for heap stack tests. Overall, they may decrease the required number of tests.

2. Static Load Test

The most correct way to deal with choose as far as possible is to present a full-assess show demonstrate pile at the site of the proposed creation piles and load it to disappointment. Be that as it may, load tests additionally are significantly more costly, and in this way should be utilized all the more reasonably. Assortments of hardware and methodology have been utilized to direct load tests. The distinctions in the hardware and methodology can impact the outcomes and turn into the purpose of level headed discussion among engineers. Along these lines, there is no single right limit with regards to generally piles. In any case, engineers evaluate the exactness of every single other technique by contrasting them with full-scale load tests.

. Description of tested piles:

The insights concerning the piles secured by this paper are shown in Tables (1) and (2) in Informative supplement (A).

. Test set-up:

The loading frame was designed to apply a maximum axial compressive load of 800 tons plus more than 10% in order to accommodate the required load increments for loading test stages as recommended by the Specifications of **ASTM D1143 / D1143M – 07**. The tests were carried out by al-Tariq Bureau for Engineering Consultation & Pile Tests.

3. Instrumentation:

Load and settlement data were recorded at various times throughout the testing along one cycle of loading and unloading. The load was controlled and measured by a load gauge connected to a hydraulic jack resting over the pile. Settlements were measured by four displacement gages attached to the top of pile and from bottom to the steel reference beams, which are sitting, directly by supports on the natural ground level. Settlements of the pile due to each loading increment and unloading decrement were obtained by averaging the four readings of the displacement gages. The loading frame is shown in Figure (2).

4. Test procedure:

The present test is intended to determine if the pile has adequate capacity throughout one cycle of loading and unloading under a static compressive load applied axially over the pile. The test starts by loading 1.2 time of the estimated compressive bearing capacity of the tested piles through 9 load increments then unloading the total applied load through 5 load decrements.

The present test is carried out correspondingly to the Chinese Specifications (according to the site specifications) and shown in Table (3) in Appendix.

5. Site description

The site is located in Wassit Governorate /Al-Zubaidiya city for about 90 km south of Baghdad. The project on this site is named (Iraqi Wassit Power Plant).

Soil investigation was carried out to find the soil properties and bearing capacity for different depths (0-45m) and boreholes. Disturbed and undisturbed samples were taken, SPT test was also carried out at this investigation. The soil was very stiff brown silty clay to stiff brown sandy silty clay from depth from (0-13.5 m) and dense to very dense gray sandy layer at depths between(13.5m to 28.5m),and very dense brown silty clayey sand at depths (28.5m to 34.5m) . The last stratum of soil (34.5 to 45 m) was very dense gray sandy layer. This paper analyses the results of four piles constructed in this project to depths shown in borehole log figure (1) and the soil properties are show in table (4) in Appendix (A).

6. Analysis and Discussion Data

This paper introduces the information examination on four instrumented exhausted piles. The depictions of the piles are sketched out in next area. Every one of these piles were established in two sorts of arrangement. Every development has its own trademark and impact on the pile and relating comes about. The static test information is investigated utilizing different techniques accessible. CAPWAP (Case Pile Wave Investigation Program) is additionally talked about to break down the dynamic test information in .At long last the outcomes are looked at between static load and dynamic load tests.

7. Static Load Test Data Analysis

There are different strategies for understanding proposed by different creators to get the piles disappointment load limit from load distortion bend got in a static load test by (Fellenius , 1980). The accompanying techniques are utilized for acquiring the pile limits:

1) Davisson's strategic Method,
2) Decort Extrapolation technique,
3) Chin-Kondner Extrapolation technique,
4) Mazurkiewie Method,
5) De Beer's technique Method,

The accompanying sections talk about quickly the translation of the consequences of SLT as sketched out by Fellenius (1980).

. Davisson's technique (Davisson's Offset Limits) which suggested by Davisson (1972) to acquire the pile relating to the development which surpasses the versatile pressure of the pile(Δ=PL/EA)by an estimation of 3.8mm in addition to a factor equivalent to the breadth of the pile separated by 120 (OC=3.8+D/120). This method was created in conjunction with the wave condition examination. Bengt. H. Fellenius (1980).

Decourt's Extrapolation Method proposed by Decourt (1999) where each load of the test is divided by corresponding settlement the resulting value is plotted the applied load, the ultimate load is defined as intersection of A linear regression line at the last points with the load axis. (Bengt. H. Fellenius 1980).

. Chin-Kondner and Modified Chin Methods proposed by Chin where he expect that the connection amongst load and settlement is hyperbolic. In this strategy, every settlement esteem is isolated by its relating load esteem. These are plotted against the settlement. After some variety, the plotted esteems will fall roughly on a straight line. The opposite incline of this straight line demonstrates Chin– Kondener Extrapolation Limits.Bengt. H. Fellenius (1980).

Mazurkie (1972) outlined a technique where a progression of equivalent pile head development lines are self-assertively picked and the relating load lines are built from the convergence of the development lines with the pile development bend. From the convergence of each pile line with the pile pivot, a 45º line is attracted to cross with the following burden line. These crossing points

fall roughly on a straight line the convergence of which with the pile hub characterizes the disappointment load. This strategy considers a suspicion that the pile development bend is around illustrative. (Bengt. H. Fellenius 1980).

De Beer (1967) and De Beer and Wallays (1972) proposed a strategy, in which the piles advancement regards are drawn in twofold log chart. Precisely when the respect falls on two around straight lines, the convergence reason for these portrays the disappointment respect. (Bengt. H. Fellenius 1980)

All the above strategies will give diverse extreme ability to a similar pile load twisting information. The pile limit got for the piles are classified in Table (1). A run of the mill diagram including all the disappointment loads got on from every one of the strategies is as in Figure (3). Figures (4) to (8) present the results of static load test with estimation of the pile ultimate load capacity obtained using the aforementioned methods.

From figure (3), chin Kondner and modified chin techniques give most noteworthy limit esteems contrasted with the various strategies for every one of the piles. The qualities acquired from Button's strategy are 5% to 15% higher than Davisson's technique. A definitive limit acquired from De Lager's strategy for the piles are bring down by 18% to 28% of the limit got from Davisson's technique. In this way, the limit from the Davisson's technique is utilized on the grounds that it is more preservationist, enables more static tests to achieve "disappointment" as opposed to different strategies (Likins et.al, 1996).

Dynamic Load Test (DLT)

DLT is viewed as a propelled strategy used to survey rapidly the limit of the pile notwithstanding other imperative data of a foundation pile. It can be utilized with thrown set up concrete piles, precast piles, wooden piles and also steel piles and, this test is more practical and speedier than static tests with dependable outcomes (Goble, 1988).

Dynamic load testing results involve the following:

1- Load capacity of pile
2-Maximum stresses.
3- Skin friction distribution
4- Toe resistance.
5-Displacement of pile.

(CAPWAP) Wave Analysis Program of Pile

(CAPWAP) is a PC program that consolidates the wave condition's pile and soil show with the case technique for forces and speeds from PDA. The CAPWAP arrangement solution incorporates the static total resistance, skin friction and toe bearing of the pile, notwithstanding the soil resistance conveyance, damping variables, and soil stiffness. The program ascertains acceleration, speeds, displacements, waves up, waves down and forces at all focuses along the pile. The system utilized by CAPWAP incorporates contributing the power follow got from PDA and change the soils parameters until the point that the speed follow got from PDA can be reproduced. It ought to be seen that the inverse method (i.e., input speed follow and produce the power follow) can likewise be performed. At the point when the match acquired is inadmissible, it is important to adjust the soil parameters, until the point when agreeable match comes about. Subsequently, the way toward running CAPWAP is viewed as an iterative one.

PDA Test Data Analysis

Pile limit got from the technique of CAPWAP examination on the PDA test comes about is thought to be completely assembled if the net arrangement of 3 mm at the season of tasting (Pile Driving Analyzer Manual , 1997). In a Pile Driving Analyzer test, the limit is acquired from CAPWAP examination for a chose blow.

In the CAPWAP technique, the pile is demonstrated by a progression of ceaseless pile fragments, elasto -plastic springs (statics resistance), and dashputs (dynamic resistance) display

the soil resistance as in Figure (9). The power and increasing speed information from the PDA are utilized to evaluate pile power and pile movement, which are two of the three questions.
The staying obscure is the limit conditions, which are characterized by the soil model. To start with,
sensible assessments of the soil resistance appropriation and shudder and damping parameters are made. At that point, the deliberate increasing speed is utilized to set the pile display in movement. The program at that point figures the balance pile head drive, which can be contrasted with the PDA decided power. At first, the processed and computed pile head forces won't agree with each other. Changes are done to the soil model suppositions and the figuring system repeated.

With every examination, the program assesses the match quality by accepting the supreme estimations of the relative contrasts between the deliberate and measured waves. The program figures a match quality number for every investigation. Through experimentation cycle modification procedure to the soil model, this soil is refined until the point when no further understanding can be gotten amongst measured and registered pile powers.

Tables.2 and 3 represent the pile capacities and settlements according to static and dynamic tests.

Conclusions

The results acquired from this analysis study empowers a stage for correlation between SLT comes about and that of dynamic test outcomes. In view of the yield, the accompanying conclusions can be determined:

1- The settlements of the piles are notwithstanding less (5-10) mm amongst static and dynamic load tests at working design load. At total test load, dynamic load test foreseen settlement is littler stood out from that of static load settlement measured.

2- The pile load bearing capacity are relying upon the method used to assess a definitive limit. In light of the outcomes, the Davisson's technique method is tantamount to that of CAPWAP investigation for SLT and DLS and appropriate technique for assessing the pile capacity in the both methods.

Table (1) Pile bearing capacity for static load test using different methods

Methods	P1 (ton)	P2 (ton)	P3 (ton)	P4 (ton)
1	273	370	373	467
2	278	377	378	382
3	283.3	375	380	475
4	280	380	370	460
5	230	280	280	350

Table (2) Pile Capacity.

Pile No.	Pile capacity(ton)	
	SL. Test	PDA test
Pile. 1	273	425
Pile. 2	389	498
Pile. 3	389	678
Pile. 4	500	558

Table (3) Pile settlement.

Pile No.	Working Load, WL (ton)	Test Load (ton)	Settlement (mm)			
			SL. Test		PDA Test	
			WL.	TL.	WL.	TL.
Pile 1	180	270	3.65	45.7	10.52	18.5
Pile 2	267	400	6.21	41.7	18.19	21.1
Pile 3	240	360	5.62	39.5	13.97	25.6
Pile 4	300	450	3.49	40.0	8.53	11.87

Figure (1): Test Equipment a) 30 tone steel ram with hydraulic release b) Pile Driving Analyzer c) accelerometer d) transducer.

a. Load gauge controlling the load increments and decrements

b. Setting the hydraulic jack and displacement gauges over the pile

c. Entire load frame and load concrete blocks.

Figure (2): Test Equipment (hydraulic jacks and test frame).

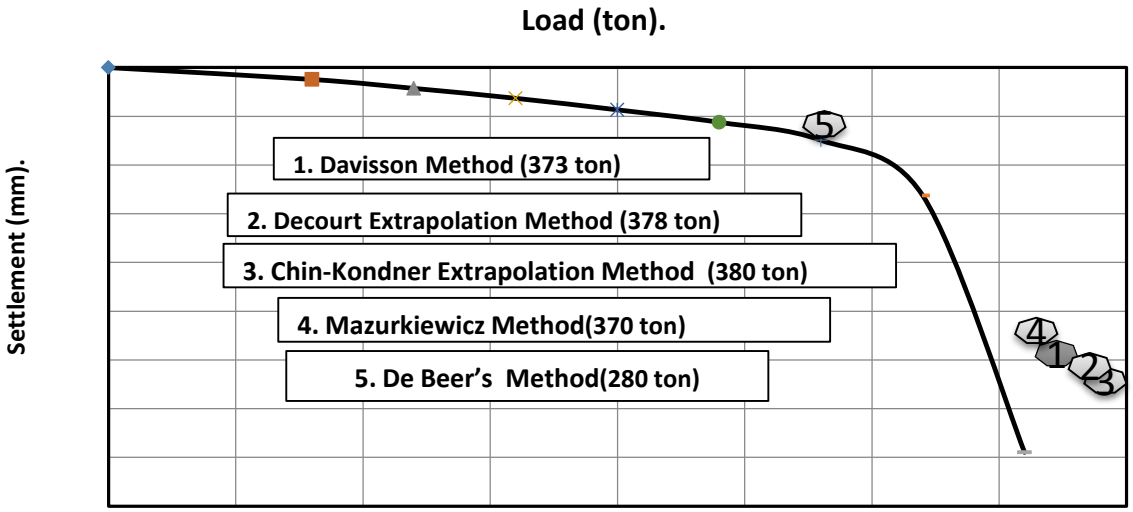


Figure (3): Comparison the bearing capacity of the pile NO. 3 with different methods as table (1).

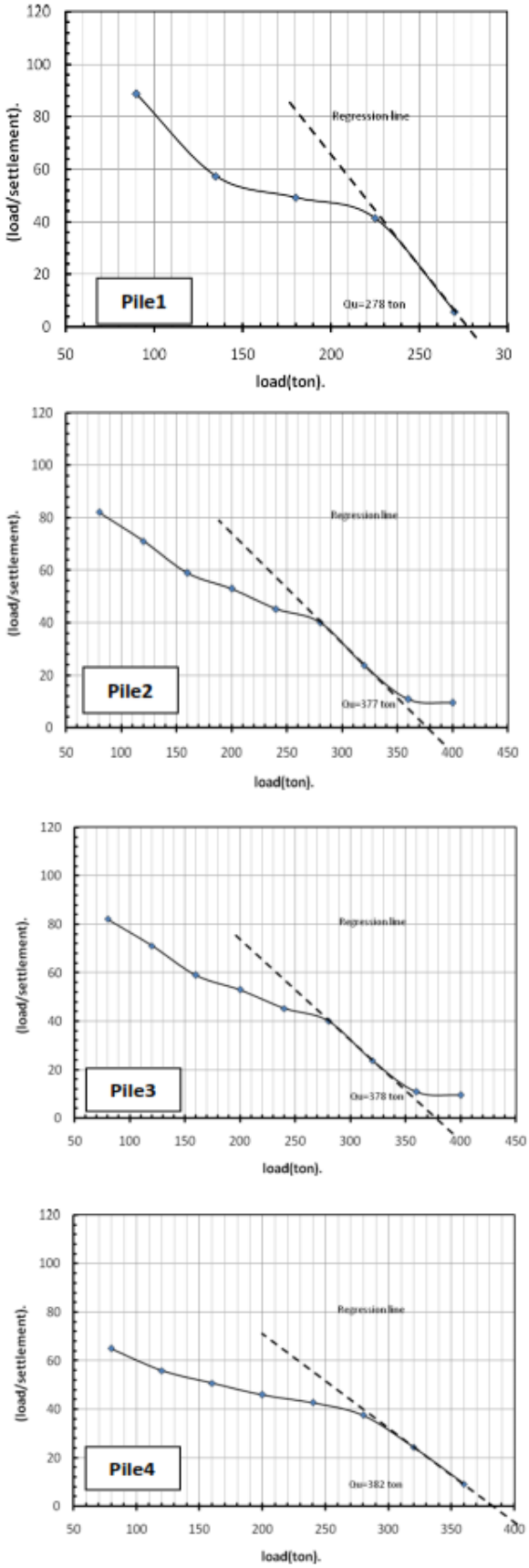


Fig.(5) Estimation of the pile ultimate load according to Decort Extrapolation Method.

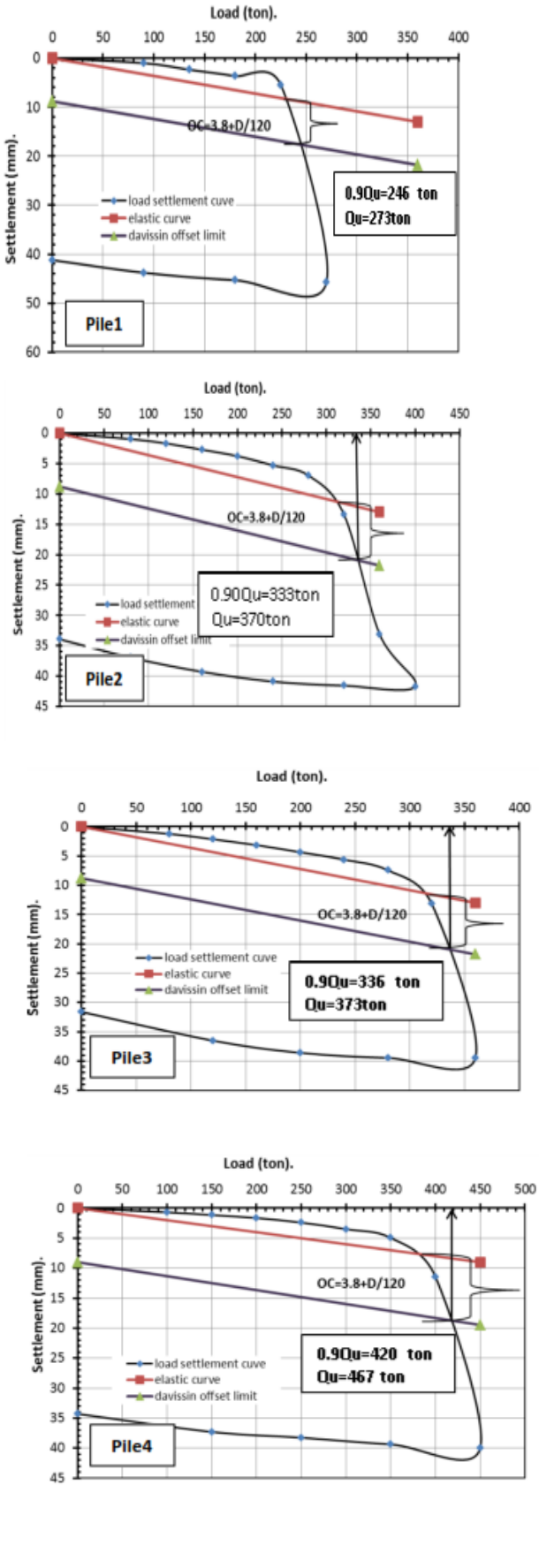


Fig.(4) Estimation of the pile ultimate failure load according to Davisson method.

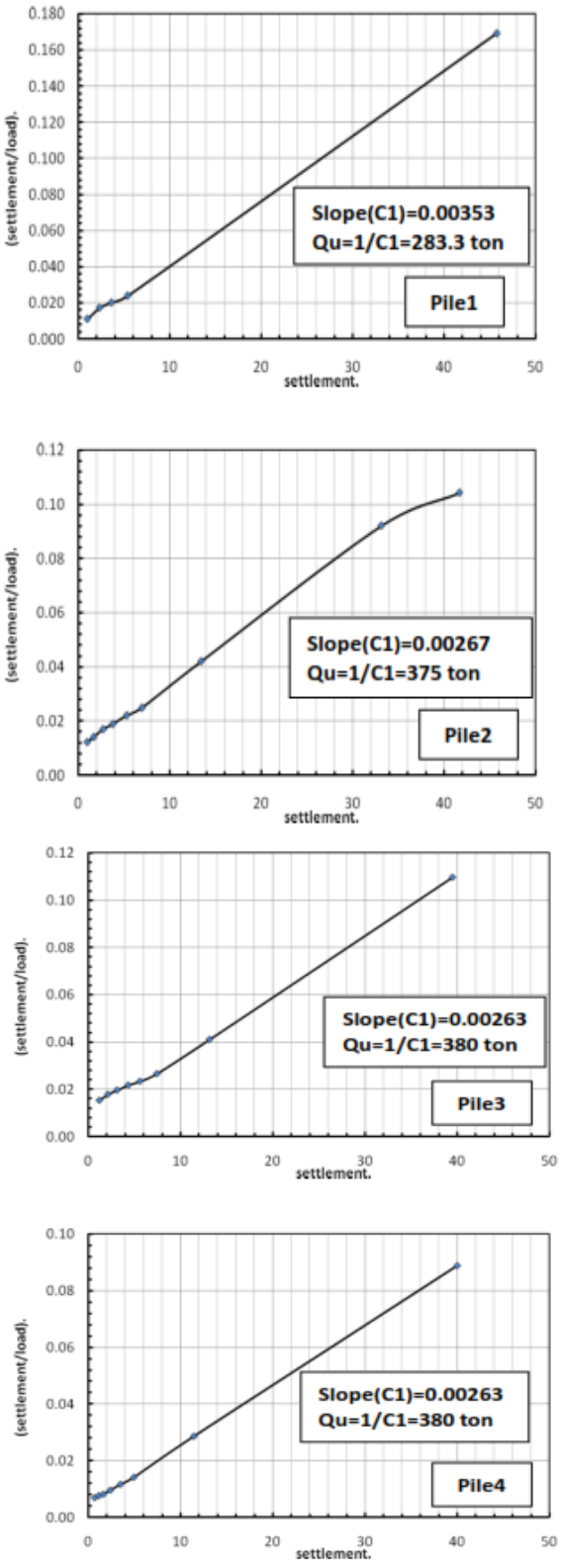


Fig.(6) Estimation of the pile ultimate load according to Chin-Kondner Extrapolation Method.

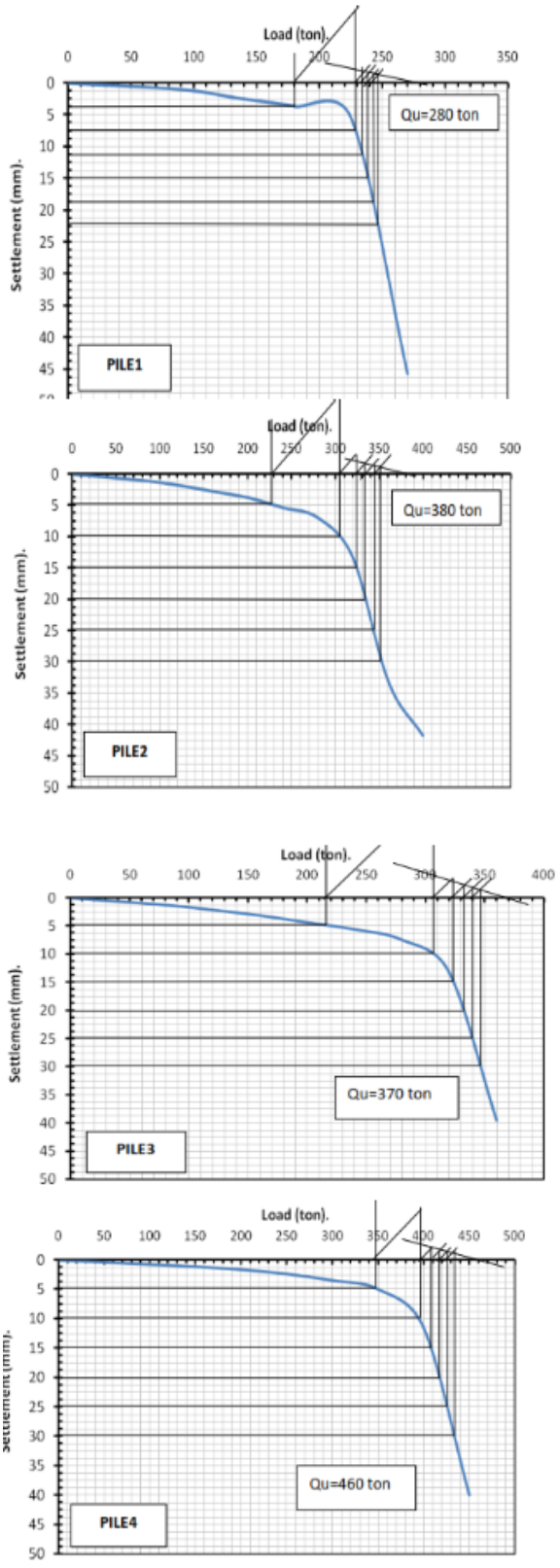


Fig.(7) Estimation of the pile ultimate failure load according to Mazurkiewicz Method.

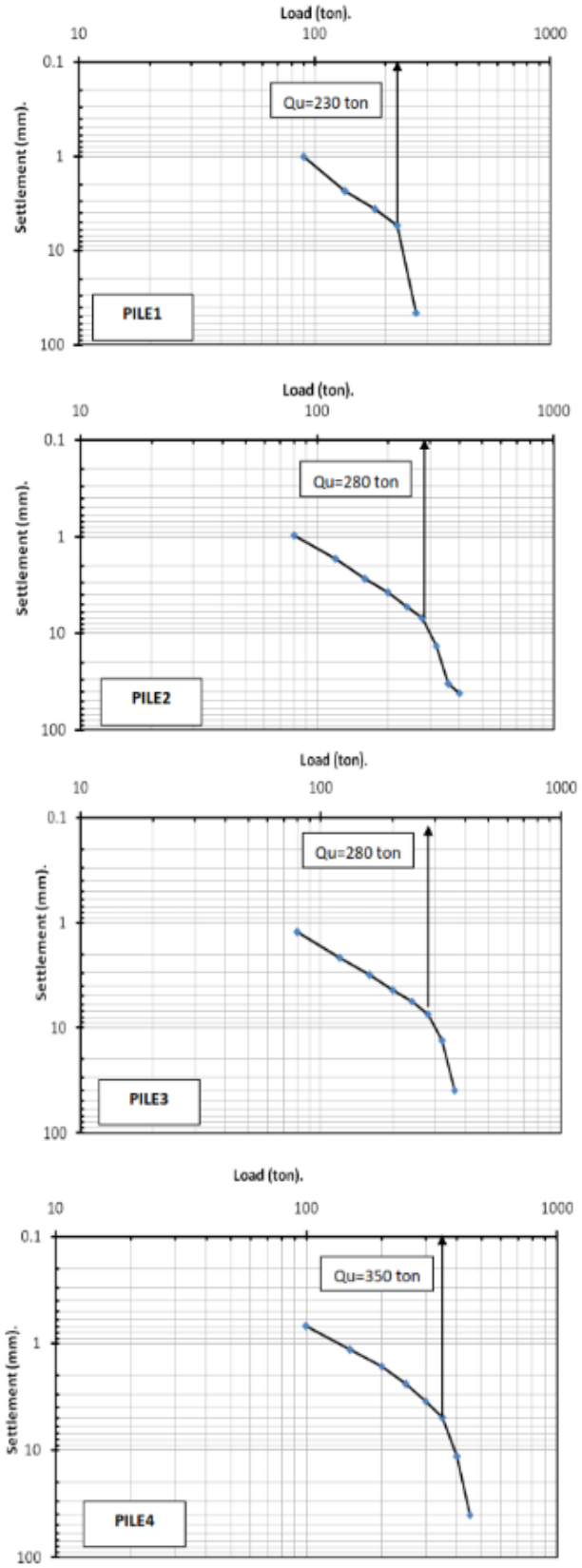
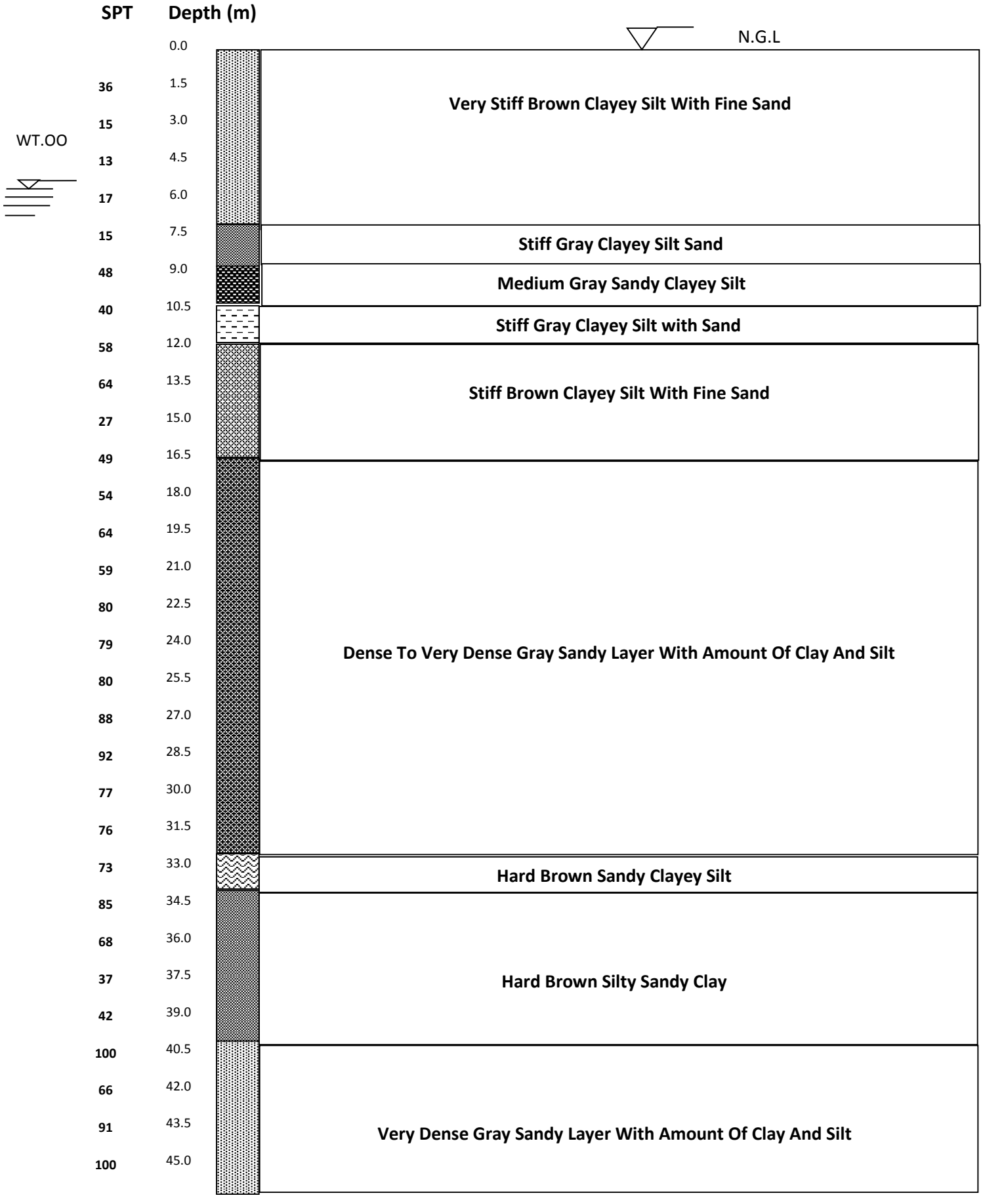


Fig.(8) Estimation of the pile Yielding limit load according to De Beer's Method.

Fig.(9): Pile – Soil Model Used in the CAPWAP Analysis (Likins and Associates) (1996)

Fig (A1) Description of Soil Strata



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