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A Correlation Between Dynamic and Static Pile Load Test Results

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Abstract

Three selected bored piles executed at Basrah area were tested both by static and dynamic pile test procedures in order to correlate their results when evaluating the piles capacities. The correlation showed that the results are close to each other in terms of load- settlement relations, but on the other hand, end bearing capacity and skin friction values obtained by the dynamics tests are far from the real behavior of piles. The reason may be due to lack of experience of crew that supervises the dynamic tests. They have to practice more dynamic tests and should build accumulated knowledge about the dynamic method of testing piles. The time is still early for the dynamic tests to replace the classical static test when evaluating piles capacities.

Keywords: Pile Test ;Static load test; Dynamic load test

مقارنة بين نتائج فحص الركائز الستاتيكي والديناميكي

الخلاصة

تم فحص عدد من الركائز المختارة بطريقتي التحميل الستاتيكي التقليدية و الطريقة الديناميكية في محاولة لربط نتائج الفحص بالطريقتين و دراسة امكانية الاعتماد على فحص الركائز بالطريقة الديناميكية دون اللجوء الى فحص التحميل الستاتيكي المعمول به حاليا. وجد من خلال المقارنة بين نتائج الفحص بالطريقتين ان هناك تقارب جيد بين الطريقتين من حيث شكل العلاقة بين الحمل و الهبوط و لكن قيم مقاومة الاحتكاك و مقاومة بهاية الركيزة التي تسجلها الطريقة الديناميكية تختلف كثيرا عن تلك المحسوبة على ضوء خواص التربة المنفذة خلالها الركائز. قد يكون السبب في ذلك هو عدم كفاءة الفاحصين في تنفيذ الفحص و خاصة موضوع ادخال بعض المتغيرات الواجب تغذيتها الى برنامج الفحص الديناميكي وعليه يحتاج الفاحصون بالطريقة الديناميكية الى ممارسة وجهد اكبر لغرض الالمام قبل اعتماد الطريقة الديناميكية في تقرير تحمل الركائز. على ضوء النتائج التي تم الحصول عليها يمكن القول بان احلال الفحص الديناميكي بدل الفحص الستاتيكي التقليدي امر يحتاج الى مزيد من الخبرة و الدراسة قبل اعتماده في العراق.

1- Introduction

Pile foundation is the part of the structure used to carry and transfer the load of the structure by means of end bearing and frictional resistance through water or soft soils to a good strata located at some depth below natural ground surface The capacity of a pile is normally calculated according to soil properties or according to pile penetration records prepared during the execution of driven piles. These static and

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dynamic calculations are normally considered as rough estimations for the pile capacities, and can be used as a guide to decide the length of working piles. The final decision of pile length and capacity must always be taken after pile testing.

2- Load Test on Piles at Site

Testing piles at the site at the present time can be done by the following methods:

Static load test

The test pile capacity is verified by conducting actual loading tests on designated piles in the structure in accordance with ASTM D-1143 (1), slow maintained loading test method, with loads applied by hydraulic jack during certain periods of time. The safe allowable load is determined from the load- settlement curve generated by the incremental loading. This type of testing is widely used in Iraq.

Dynamic load test

Dynamic measurements are used to evaluate hammer and driving system performance, pile driving stresses, pile structural integrity, and pile bearing capacity.

Dynamic monitoring is conducted by the pile driving analysis (PDA) consultant in accordance with ASTM D 4945 (2).

The use of this type of testing is still very limited in Iraq, as most of the designers are still have doubts about it.

3- Dynamic and Static Testing Results

Three pile dynamic tests were carried out at Basrah Water Towers & Ground Reservoirs- Site 3. The aim of the dynamic testing was to evaluate pile capacity and measure settlement under applied load and compare that with the static load test results. The field tests were conducted in 2007. This paragraph presents the results of dynamic pile testing and analysis using the Pile Driving Analyzer, PDA.

Signal matching analysis such as CAPWAP (6) is considered as a standard procedure for the pile capacity evaluation from high strain dynamic pile testing data. Using one pile top measurement, like the downward stress wave, CAPWAP iteratively alters the soil model to calculate and obtain a best match with the complimentary wave, such as the measured upward traveling wave.

Although there are many applications of dynamic pile testing, load capacity being the main one. The ability to accurately predict static capacity from dynamic pile testing has resulted in many studies (4,5), and has been the focus of dynamic pile tests on many project sites. Standard practice requires performing signal matching on the data to more accurately determine capacity from the dynamic tests.

Reliable correlations for long term capacity from dynamic tests with static load tests require simple guidelines. For driven piles, dynamic tests should be performed during a re-strike after a sufficient period to allow soil strength changes to stabilize. Ideally, the time after installation for the dynamic test should be similar to that of the static test, and preferably as soon as possible after the static test completion. However, time pressures in the construction schedule often require dynamic testing after a limited wait time, and the full “setup” increase is then not achieved. Testing drilled shafts or auger cast piles requires the concrete or grout to achieve a sufficient strength, which indirectly allows the soil to recover from the effects of drilling process. The driven or drilled pile must also experience a reasonable net set per blow (typically 2 mm or more) to mobilize the full capacity. Since dynamic testing of drilled shafts often results in a small set per blow, the capacity predicted would be based on the conservative side.

4-Dynamic Pile Testing and Analysis

Dynamic pile testing measures pile force and motion under hammer impacts with a system consisting of reusable strain transducers, accelerometers, and a Pile Driving Analyzer (PDA(7)) unit. Real-time data processing produces testing results that allow for evaluations of hammer system performance, pile driving compression and tension stresses, pile structural integrity, soil resistance distribution, and pile static load capacity. To quantify the soil resistance effects, the measured data are analyzed with the CAPWAP program which employs sophisticated signal matching techniques. CAPWAP results include static resistance forces along the pile shaft (i.e., skin friction) and at the pile toe (i.e., end bearing), soil quake and damping values in friction and end bearing, and a simulated pile static test (load-movement graph).

Soil conditions

The upper soil layer (about 5m in depth) of the selected site at Basrah consists of medium to stiff cohesive soil (9). The allowable bearing capacity for this layer is about (4.5 t/m^2). This layer is followed by a soft to very soft clayey silt layer which extends to about (23m) in depth. The allowable bearing capacity estimated for this layer is ($2.5 t/m^2$).

Details of tested piles

The piles being tested were 700 mm. in diameter bored concrete piles. The length below gauges was 21.50, 22.80, and 22.00 m. For piles No. 54, 76, and 72. The concrete strength used to cast piles was 21 MPa with a minimum cement content of 420 kg per cubic meter and a slump ranging between16-20 cm. The piles were tested using a 5 tons hammer falling from a height of 1, 1.5, and 2 m.

Test equipment

A Pile Driving Analyzer and its associated pile top force and velocity transducers were used to conduct the dynamic pile test.

Two strain transducers and two accelerometers were attached to the pile head. They were mounted on opposite sides of the pile to cancel bending effects during each strike of the hammer. The signals of strain and acceleration were conditioned and processed by PDA (8).

The PDA is a micro-processor based signal conditioner and digital computer. Signals of pile top force and velocity were measured and analyzed during each strike of the pile driving hammer and stored in the Analyzer. The pile top force and velocity-time curves were displayed on laptop computer screen. Real time analogue signals of the pile top force and velocity were also recorded using the PDA and later stored in the field computer unit.

The PDA (8) on site uses a program based on closed form Case-Goble solutions to compute static pile capacity from the pile top force and velocity data. This is subsequently checked with the computer program

CAPWAP to confirm the static pile capacity obtained on site.

Pile dynamic analyzer field testing and results

Dynamic testing on piles was conducted by striking the piles several blows during the re-striking process. During testing of the pile, complete dynamic measurements were obtained for each hammer blow delivered to the pile. The field results along with comments for each blow are summarized in Table 1.

The PDA measures the total (static plus dynamic) resistance acting on the pile. The portion of total resistance that is computed as static resistance by the analyzer is determined by the soil damping factor Jc set into the analyzer. A more accurate independent measure of the applicable soil damping factor was determined using a CAPWAP analysis.

CAPWAP analysis

A selected PDA field recording of force and velocity data for a blow delivered to the piles was further analyzed using the CAPWAP (6) (Case Pile Wave Analysis Program) computer software. The analysis involved applying the measured pile top velocity time record to the top of a lumped-mass and spring wave equation model of the pile.

The program computes the pile top force-time record and this is then compared with the actual measured force-time record. The pile and soil resistance model is then adjusted in an iterative procedure until good match is obtained between measured and computed forces.

The pile and soil models can then be used to determine the estimated static load-settlement curve. The results of CAPWAP analysis for a typical blow are briefly summarized in Table 2.

5-Pile Static Load Testing

The same 3 piles previously tested by dynamic method were subjected to a full-scale conventional compression static load test. The static load test was performed in general accordance with the requirements of Standard Specifications ASTM D-1143-1994 Test procedure. Load was applied to the pile top with one hydraulic jack against dead load. The loads were applied in 25% increments of the design load, and each increment was held for approximately 60 minutes. Pile movement dial gauges were used on two sides of the pile to record the deflection values of pile during test.

6-Correlation of Static and Dynamic Testing Results

The resulting pile dynamic record was analyzed using CAPWAP for assessment of static pile load-bearing capacity, soil resistance distribution, and simulation of pile-top static load-movement graph. Figures (1), (2) and (3) includes a plot of the CAPWAP analysis result (pile-top static load-movement graph), which correlate very well with the actual full-scale conventional static load test results.

7-Conclusions

From the three comparisons between the results of testing of the three piles by static and dynamic tests; the following conclusions can be raised:-

1- Good agreements are found between the static and dynamic tests results regarding pile capacities.
2- The difference between CAPWAP and static load test

results are generally well within the range of the static test failure loads when adopting the different evaluation methods shown in Table (3), and are comparable to the statistical average of the different static test evaluation methods.

3- Considering the extra information of hammer performance evaluation, pile integrity inspection, and driving stress determination; the dynamic testing can solve more problems and answer more questions than conventional static testing method.

4- Considering the low cost of dynamic testing and the obvious flexibility of this method, it should be part of most quality control programs for pile foundations accuracy of the CAPWAP capacity prediction.

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9. Soil report gfdsa

Table (1) Summary of PDA field results

Pile no.	Drop Height in m.	Measured Capacity in tons	Net Settlement in mm.	Total Settlement in mm.	Comments
54 –S3	1.0	84	0.0	2.0	-
	1.5	134	0.0	3.0	Used for analysis
	2.0	162	0.0	4.0	-
72 –S3	1.0	107	0.0	2.0	-
	1.5	135	1.0	3.0	Used for analysis
	2.0	141	3.0	4.0	-
76–S3	1.0	80	0.0	2.0	-
	1.5	106	1.0	3.0	-
	2.0	106	4.0	4.0	Used for analysis

Table (2) Summary of CAPWAP analysis results

Pile No.	54 –S3	72 –S3	76 –S3	Units
Pile Diameter	700	700	700	cm.
Measured Pile Capacity	183.5	169.0	146.8	Tons
Skin Friction	145.7	116.3	92.9	Tons
End Bearing	37.7	52.7	54.0	Tons
Net Displacement	3.013	3.075	2.092	mm.
Total Displacement	8.640	8.336	6.857	mm.
Compressive Stress	0.06	0.06	0.04	Ton /cm.^{2}
Tensile Stress	0.0	0.0	0.0	Ton /cm.^{2}

Table (3) Predicted ultimate pile capacity by different evaluation methods compared with dynamic method

Pile Location	Pile Type	Predicted Ultimate Pile Load (Tons)										
		Dynamic method	Davison	Chin Konder	Brinch Hansen	Decourt	Brinch Hansen	De Beer	Vander veen	Fuller & Hoy	Butler & Hoy	4% of pile dia.
AL-Hyania W.T.P- S3 P76	Bored D 70 cm	147	155	134	141	159	150	150	160	151	160	155
AL-Hyania W.T.P- S3 P54	Bored D 70 cm	183	186	163	163	167	169	160	170	173	188	183
AL-Hyania W.T.P- S3 P72	Bored D=70 cm	169	179	154	161	164	172	160	170	168	179	175

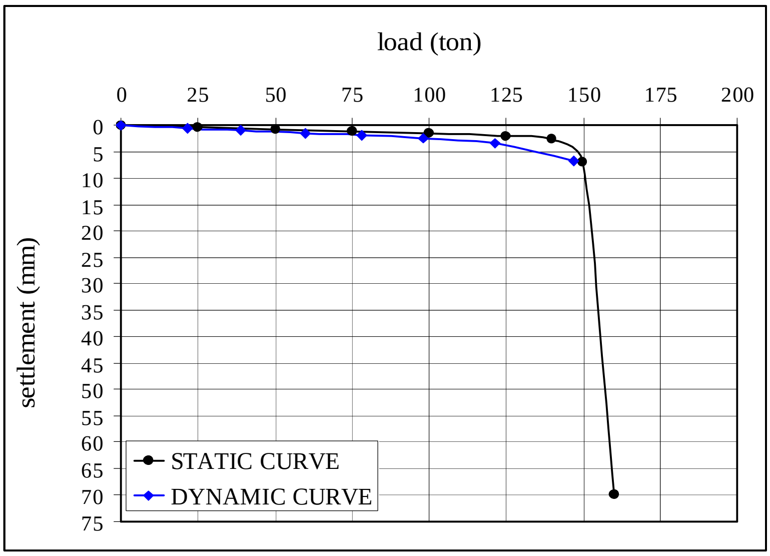

Figure (1) Comparison between actual (Static Load Test) and simulated (PDA/CAPWAP Dynamic Test) results (P76- S3)

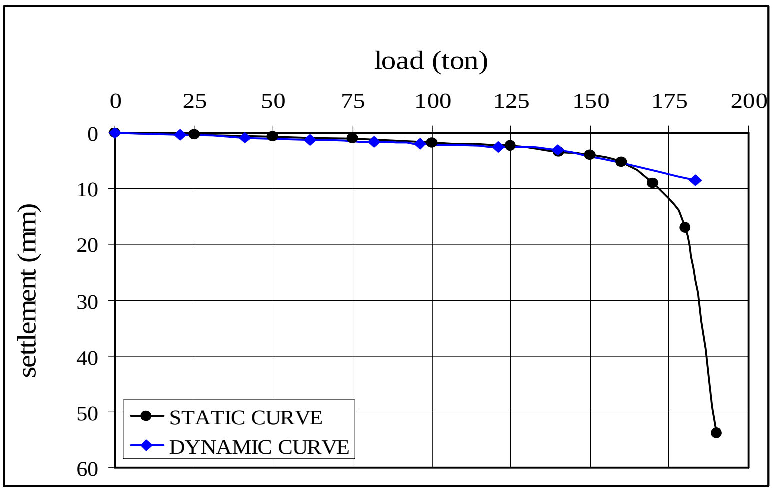

Figure (2) Comparison between actual (Static Load Test) and simulated (PDA/CAPWAP Dynamic Test) results (P54- S3).

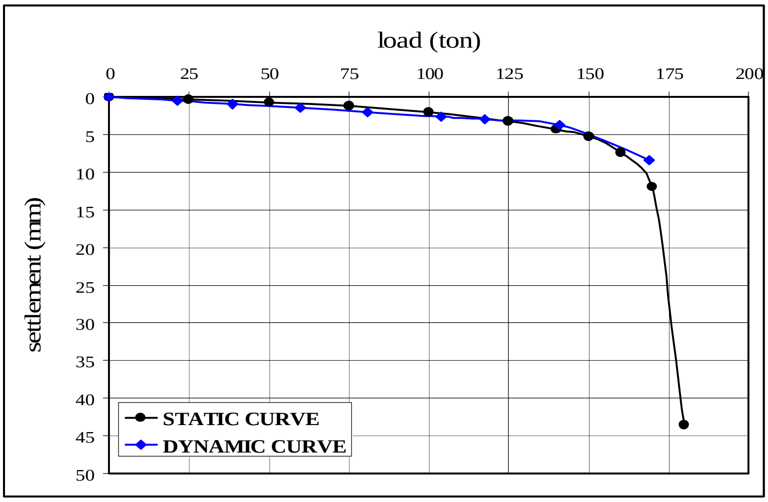

Figure (3) Comparison between actual (Static Load Test) and simulated (PDA/CAPWAP Dynamic Test) results (P72- S3).