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# THE CORRELATION BETWEEN STATIC PILE CAPACITY AND DYNAMIC PILE CAPACITY IN DIFFERENT SITES IN BASRA CITY, CASE STUDY

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**ABSTRACT:** The present research concerns the correlation between the static pile test and the dynamic pile test of driven piles in Basra city by using two types of pile, which are the precast reinforced concrete piles and steel tube closed-end piles. 100 pile tests in the Majnoon oil field, which is located in the north of Basra City, Southern Iraq, are considered in this paper, which focuses on the ultimate pile capacity as the criterion in establishing the correlation between the two test types. The CAPWAP program was used in determining the dynamic pile capacity, while Davisson's method was applied as a criterion in estimating the ultimate pile capacity. The Results have shown that a very strong correlation between the two types of pile tests and the dynamic pile tests, which gave higher values of the pile capacity than the static pile capacity and the case method. Also, the results indicate that the damping factor of soils in dynamic tests showed some variation larger than the quake value from the values of the case method.

*Keywords: Static load test, Dynamic load test, Case method, CAPWAP analysis, Damping factor, Quake value.*

## 1. INTRODUCTION

In the compression pile engineering problems, the researchers are interested in many subjects. The first one is related to the pile capacity regardless of its state (ultimate or working state), while the second subject is interested in the load transfer mechanism for both the shaft (side friction) and the end bearing (tip point bearing). The third subject focuses on the pile settlement either during construction or within the service lift. The last subject is associated with the influence of time on the pile capacity and soil properties. Here, establishing the pile capacity (ultimate and/or working) state represents one of the most important aspects in the pile engineering field. The story of the pile foundation starts from the soil investigation, leading to the specific analysis or design method employed in the project. There are many techniques available to satisfy this goal, such as the analytical methods, the in situ method, the dynamic formula, the static pile test, and the dynamic pile test. The application of above techniques gave a different results and the variation of these results make amore confuse in the analysis accuracy, design integrity, and the adequate construction of deep or pile foundation. But, one of major problem of the piling foundation design is the variation of the pile capacity with time which reflected by two effects that are well known as the setup effect (the increasing pile capacity value in cohesive soils) effect and relaxation effect (the decreasing pile capacity value in granular soils).

From above five techniques, the static pile test SLT and the dynamic load test DLT that conducted to determine the pile capacity are considered the more accurate techniques other than the others (Static design equations, in situ test methods, Dynamic formula) but due to many the factors such as the cost and time of SLT caused to searching to and leading to more economical and rapid test required and these matter are satisfied by employing the dynamic pile test DLT. Below are some researches and studies which conducted at last year's related to the both pile type tests. Numerous authors have established relations between static and dynamic load tests on piles since the 1980s keeping in the mind this processes required an adequate load tests (SLT, DLT) execution for a satisfactory correlation. Moreover, further analyze of dynamic test output data can be improvement to determine the distribution of soil shaft resistance (skin resistance), toe resistance (tip point resistance), quakes (shaft and toe), and damping ratio (shaft and toe) so that the best possible match between a computed pile top variable, such as the pile top force, and its measured equivalent serves as the basis for results [1]. For more information, below are some studies and researches about the paper subject.

Micheal A. [2] studied and compared the results of a static load test which conducted first then followed with dynamic load test. The ultimate capacity was gotten using the Davisson's method which gave the lowest value compared to other methods. The test results showed that a good agreement had been achieved between both the test with plus minus 2mm at working load in terms of settlement. Also, the settlement predicted in the dynamic load test was lesser compare to static load test.

Frank et al. [3] described the process of the three analysis phases utilizing typical offshore pile which were a wave equation analysis combined with CAPWAP signal matching analysis bearing capacity assessment. Also, the paper gave guide lines for the static analysis process and a summary of limitations. Finally, the research included recommendations for the soil resistance modeling closer the open ended pipe bottom.

Jorge et al. [4] described the test program which performed on helical piles installed in Amherst campus. Seven piles had been tested by static load followed by dynamic load. The results showed that a good agreement had been obtained between the static pile test and dynamic pile test. Also, the test results were comparison with torque correlation giving higher value than the traditional one used.

Mohamed et al. [5] made a comparison between the static and dynamic load tests results to assess the facility of the pile Dynamic Test using SIMBAT method to calculate the static capacity of bored concrete piles from 4 case studies conducted in Red Sea state. The test results had been are consistent to a good extent. Also, the ratios of settlement/pile diameter were less than 1% for all piles represent conservative pile design.

McCabe et al. [5] observed a sequence of full-scale loading tests that are considered an instrumented field tests of shallow footings and the deep foundations that carried out in soft silt deposits that lie beneath much of the greater Belfast area.

Anup K. H. [6] established a comparison between static and dynamic load test methods using two full scale driven precast piles by using BNBC-2015, BNBC SPT, AASHTO-2002, driving equations. The results showed that the predicted capacity of precast driven piles using BNBC-2015 static bearing capacity has a very good co-relation with CAPWAP capacity confirmed other than the dynamic load test.

Frank R. [7] investigated the factors which effecting the dynamic pile test when comparing and calibrating with static pile test such as assessment of time dependent related to the soil resistance changes, incomplete resistance mobilization, failure criteria different failure modes in open end profiles and sensitivity to high loading rates. The paper described how to set up and perform effective test programs.

Mostafa et al. [8] used a database of 60 pile load tests (14 static and 46 dynamic pile load tests) of bored piles socketed in rock at two different sites in Dubai using the load settlement curve. The results show the pile capacity from the tests were strongly related together. Also, the pile capacities which were obtained from the dynamic test were lesser than compared to Chin deduced pile capacity.

Nafis et al. [9] investigated transitional behaviors of intermediate geomaterials (IGMs) between hard rock and soil using three static SLT and three dynamic DLT pile load test of steel H-piles in IGMs. The first pile was driven into siltstone in Wyoming while the other two test piles were driven into shale in Iowa constructing driven. It was observed that DLT under predicted the total pile resistances of piles by about 33%, 20%, and 24% when compared to SLT results based on Davisson, 10% B, and De Beers YL criteria, respectively.

Rizki et al. [10] compared the ultimate capacity of the pile based on the result of static load test, and dynamic load test for pile design in granular soil of Batam, in Indonesia using Chin-Kondner, Mazurkiewicz, Davisson, and Hansen 80% methods that obtained results of 1379, 1300, 1375, and 1182 tons, respectively.

Kamol et al. [11] studied the load and the displacement relationship of pile in five sand soils using both a physical model test and the finite element method (FEM). The results showed that in all soils that a linear relationship in the first stage of displacement of 10 percent of pile diameter and a non linear relationship with an elastoplastic-strain hardening pattern for a displacement in the range 20 percent of the pile diameter.

Nagwa et al. [12] analyzed long, large-diameter bored piles behavior under static and dynamic load tests for a megaproject located in Egypt. The results showed that the dynamic load test could be used to validate the pile capacity. Also, the settlement of dynamic load test was about 25% higher than that from the static load test.

Vincent et al. [13] 2024 conducted a comparison study between static load pile test (SLT) and dynamic pile load test (DLT) using previous 51 pile tests of both types test. The results had been provided that the outcome of an average DLT/SLT ratio of 0.9833. In addition, instrumented SLT could be compared to those from DLT, allowing for the utilization of skin resistance from both tests as an additional criterion for comparison.

The subsequent sections of this article is contained the significance of paper, methodology used for it, described the obtained results, and followed with the main conclusions.

## 2. RESEARCH SIGNIFICANCE

In present time, DLT has been considered as portion of pile testing program around the world including in Iraq in which the soils of Basra city which located at southern of Iraq have problems of strength and settlement leading to the proper foundation is piling foundation. Oil and gas industry are spreading over a wide area in Basra city and the progress of this industry requires a rapid construction technique without losing the accuracy.

Therefore, the current paper search to establishing the nature of SLT and DLT in this city. In global, this study different from the above studies by three parameters. The first one is involving two types of piles (prestress reinforced concrete and steel pile) by selecting 100 pile tests during 2017- 2025 (this large number of pile test give study more power than the studies in literature review), the second parameter is it is investigated the pile diameter effect on the SLT and DLT relationship. The third one, is studying the variation of soil parameters according to pile type and pile diameter. According to many decades, many researches and studies around the world were published to fixed the relation between SLT and DLT and to decide the nature of this relation and investigation the different parameters which effecting on it.

## 3. METHODOLOGY

Today, both the static SLT and the dynamic DLT pile testing methods are considered the main types of pile tests that are essentially used to assess the pile load capacity and corresponding settlement. Since the static pile load test is conducted at low strain and takes which meaning longer time is needed other than the dynamic pile load test. There are advantages and disadvantages for each test type. For example, the main disadvantages of SLT are the time, cost, safety considerations, and load-displacement measurements errors. In the other side, DLT is considered safe, economic, and raped but it required deep knowledge and experiences of the wave theory subject in analyzing the signal of DLT in, and good signal matching value during test. In addition DLT is still common with SLT that both tests are not applicable to estimate long term settlement of piles. Therefore, in new projects of high sensitivity, importance, and dangers as in the oil and gas field, so that it is essential together both tests in any projects such as employed in Majnoon Oil field.

### 3.1 Static Pile Load Test (SLT)

SLT is considered the primary and main test type in all projects of deep foundations especially in Basra city. Many standards cover the required steps to conducted this SLT but in this work standard ASTM D1143[14] was used in the project of Majnnon oil field. In ASTM D1143, many procedures are available such as constant penetration rate test CPR, quick load test QLT, and , maintain load test MLT in which CPR and QLT are frequently applied for trial piles verse MLT which applicable for both trial and working piles. In this paper MLT is used as specified by the project specifications so that all piles are loaded 200% of working load. The arrangement of applied load and other equipments are shown in Fig. 1.

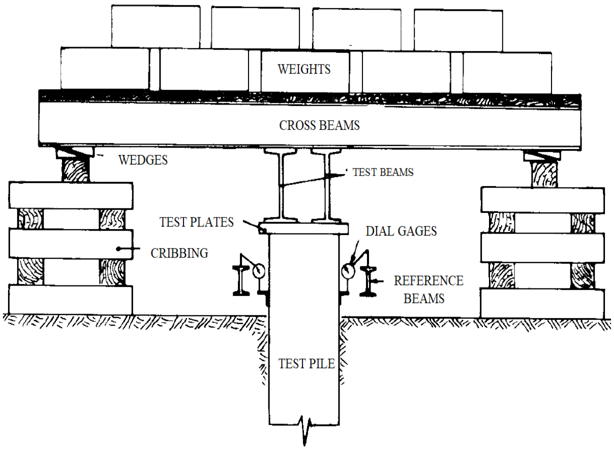


Fig. 1 Schematic Set-Up for Applying Loads Directly to Pile Using Weighted Platform [13]

### 3.2 Dynamic Pile Load Test (DLT)

The dynamic pile load test DLT is based on the research initiated in 1964 at Case Institute of Technology. The basic idea of this type of test was to evaluating the static pile capacity from measurements of pile force and acceleration under hammer impact near top pile head so that DLT has the ability to estimating soil resistance and its distribution from these force and velocity measurements obtained near the top of pile due to the impact occur due to a hammer or drop weight. In usual, dynamic pile testing and analysis are referred to WEAP analysis, PDA measurements, and CAPWAP analysis. Dynamic pile testing must be carried out after the concrete has sufficiently strengthened so that a long period wait is naturally achieved to allow the soil strength to recover from the installation process. The instrumentation and alignment are typically checked with a small initial impact. Then, blows with increasing drop height are applied until, whichever comes first: the stresses meet the pile's strength limits; the set per blow exceeds around 3 mm. Dynamic pile load test procedure is standardized by ASTM D4945-13 [15].

The impact produces a compressive wave that travels down the shaft of the foundation and then reflected from both the pile side and tip pile point. There are two known methods, based on wave propagation theory, for the analysis and interpretation of the dynamic pile load test. The CASE method was considered as direct methods and CAPWAP was considered as indirect methods [1]. Typical Arrangement for High-Strain Dynamic Testing are shown in Fig. 2.

### 3.3 Criteria of Failure

For the comparison of DLT and SLT available results, a failure criteria shall be established to define the ultimate pile capacity. Also, because not instrumented are provided for fixing in SLT which lead to become the outcome comparison from both tests using only the ultimate pile capacity meaning that the utilization of skin resistance and end bearing are not possible in SLT. Most pile load tests are not reach to the failure condition (increasing head pile settlement with constant load), therefore it is necessary to consider suitable failure corresponding to the pile tests. Shamsher [16] list 9 methods may be used to estimate the failure load from pile test but in this work Davisson method is used for two reasons. The first one is this method represented as conservation criteria as applied in previous studies mentioned in the introduction section [1 to 12] and the second reason related to the other methods are not exist a solution for many tests. The Davisson method is represented by the intercepting load-movement curve of test with as given below following line equation[15]:

$$\Delta_f = 3.81 + D/120 + (Q \times L)/(E \times A) \qquad (1)$$

Where

$\Delta_f$ = Movement corresponding to failure load.

D= Pile diameter or width.

Q= Pile load corresponding to the failure load which defined as the intersection of Davisson equation with the load-movement curve of pile test.

L= Pile length.

E= Modulus of elasticity of pile.

A= Cross sectional area of pile.

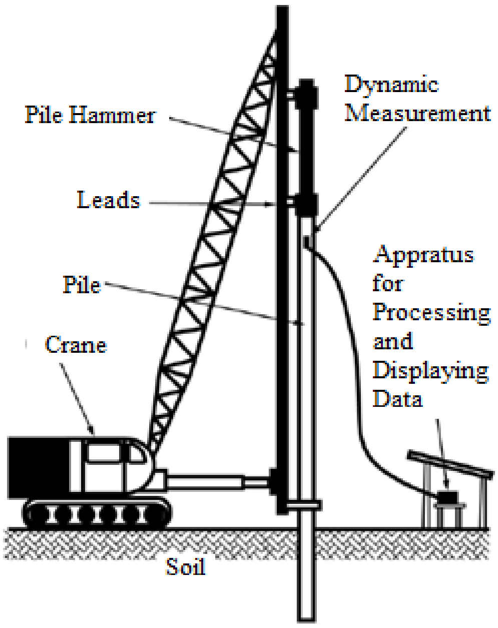


FIG. 2 Typical Arrangement for High-Strain Dynamic Testing of a Deep Foundation [14]

### 3.4 Subsurface Conditions

The site investigation of the project (in the central process facility CPF area ) involve 52 locations, ranging of depth 10 m to 25m) consisting of 12 borings and 40 CPTs. The pile driving and testing were distributed around and inside the area of the CPF project. 100 pile test were selected from the all tested piles. The idealized stratigraphy for the foundation design is summarized in Table 1.

Table 1. Idealized soil profile for pile capacity evalution

| Depth (m) | Layer | Friction Angle (°) | Shear Strength (kPa) |
|---|---|---|---|
| 0 | 1 | 30 | |
| 1.5 | 2 | | 20 |
| 10 | 3 | 30 | |
| 11 | 4a | | 30 |
| 12 | 4b | | 100 |
| 20 | 5 | 35 | |
| 22 | 6 | | 100 |

## 4. RESULTS

This study evaluates 100 pile load tests selected from previous investigations conducted in the Majnoon oil field as part of the CPF 2 project during the period 2017–2025. The test program involved two types of piles: precast concrete piles with a square cross-section of 40 cm, and tubular steel piles with diameters of 40 cm, 50 cm, and 60 cm, closed at the base. A summary of these tests is presented in Table 2. All load tests were performed 21 days after pile installation to account for the soil setup effect. The detailed results are provided in Tables 3 - 6 and Figs.3 - 6.

The findings are categorized into three key aspects. The first concerns the load–movement relationship, which illustrates the behavior of piles under applied loading. The second examines the correlation of failure loads obtained from static load tests (SLT) and dynamic load tests (DLT). The third investigates how variations in soil properties along the pile shaft and at the pile tip influence DLT results.

It should be emphasized that pile head movement under applied load is not singular, but rather a combination of three components: elastic compression of the pile, displacement along the shaft, and settlement at the tip.2-Shaft pile movement which simulated by some standards as t-z curve which required movement 0.01 times pile width or diameter to reach the ultimate shaft resistance and take linear nature as in previous point. 3-Tip pile movement which simulated by some standard as q-z curve which required movement 0.1 times pile width or diameter to reach the ultimate shaft resistance and take nonlinear nature between the applied load and corresponding movement.

Therefore, as the load increases from zero to first load increments the load-movement curve takes the linear shape as mentioned in Fig. 3 which display the load movement curves of precast reinforced concrete pile and Fig. 4 for steel piles of diameters 600 mm. As mentioned from Figs. 3 and 4, the load movement curve is divided into three different segments. The first segments is approximately having linear shape either using SLT or DLT and it extend from starting of test to movement approximately equals to 10±2 mm while the second portion extend from the end of first portion until reach to the ultimate test load in which this portion has non linear nature noting that the two portions represent the loading part of SLT and DLT. The third portion of the curve simulated the unloading portion which has the linear shape.

Table 2. Summary of pile tests

| Item | PPRC400 | STL400 | STL500 | STL600 |
|---|---|---|---|---|
| Pile Section | (400×400) mm | 400 mm Dia. | 500 mm Dia. | 600 mm Dia. |
| Pile Length | 22 m | 21 m | 21 m | 21 m |
| Pile Grade | C45 | 250 EP | 250 EP | 250 EP |
| Load Test | 230 | 100 | 160 | 200 |
| SLT No. | 15 | 10 | 15 | 10 |
| DLT. No. | 15 | 10 | 15 | 10 |
| Tip Pile Soil | Hard Clay | Hard Clay | Hard Clay | Hard Clay |

Table 3 Main details of PRC pile tests

| SLT (ton) | DLT (ton) | Shaft Damping Ratio | Toe Damping Ratio | Shaft Quake (mm) | Toe Quake (mm) |
|---|---|---|---|---|---|
| 222 | 250 | 0.3035 | 0.4454 | 6.825 | 1.295 |
| 188 | 214 | 0.3536 | 0.5148 | 5.628 | 2.354 |
| 227 | 247 | 0.5824 | 0.6197 | 5.236 | 4.875 |
| 219 | 253 | 0.5352 | 0.7072 | 4.859 | 3.731 |
| 213 | 244 | 0.6129 | 0.8234 | 7.221 | 5.236 |
| 208 | 238 | 0.4529 | 0.6772 | 5.237 | 4.463 |
| 198 | 234 | 0.4268 | 0.5117 | 7.5 | 3.774 |
| 213 | 235 | 0.678 | 0.7987 | 6.074 | 4.615 |
| 197 | 221 | 0.5284 | 0.7892 | 5.488 | 4.125 |
| 210 | 228 | 0.3843 | 0.7638 | 6.314 | 2.875 |
| 198 | 224 | 0.3036 | 0.7469 | 7.268 | 3.645 |
| 177 | 198 | 0.3404 | 0.6033 | 7.458 | 6.335 |
| 217 | 237 | 0.2115 | 0.2974 | 7.112 | 4.695 |
| 216 | 245 | 0.6654 | 0.3854 | 7.336 | 4.004 |
| 201 | 219 | 0.1892 | 0.4665 | 6.995 | 3.325 |

Table 4 Main details of 400 mm diameter steel pile tests

| SLT (ton) | DLT (ton) | Shaft Damping Ratio | Toe Damping Ratio | Shaft Quake (mm) | Toe Quake (mm) |
|---|---|---|---|---|---|
| 95 | 112 | 0.1461 | 0.8312 | 5.904 | 3.758 |
| 92 | 110 | 0.2661 | 0.8792 | 4.002 | 2.501 |
| 89 | 104 | 0.7952 | 1.1149 | 2.854 | 2.505 |
| 85 | 102 | 0.4328 | 0.5309 | 2.547 | 3.308 |
| 81 | 101 | 0.1595 | 0.3287 | 4.878 | 4.627 |
| 93 | 113 | 0.2348 | 0.5366 | 3.689 | 3.028 |
| 80 | 106 | 0.7071 | 0.7102 | 3.614 | 2.145 |
| 82 | 105 | 0.5035 | 0.8025 | 5.454 | 3.825 |
| 77 | 101 | 0.3655 | 0.8365 | 4.562 | 2.424 |
| 78 | 109 | 0.7515 | 1.0581 | 5.521 | 6.325 |

Table 5 Main details of 500 mm diameter steel pile tests

| SLT (ton) | DLT (ton) | Shaft Damping Ratio | Toe Damping Ratio | Shaft Quake (mm) | Toe Quake (mm) |
|---|---|---|---|---|---|
| 83 | 115 | 0.3874 | 0.8287 | 7.127 | 3.187 |
| 147 | 172 | 0.5625 | 0.4515 | 5.9655 | 2.663 |
| 152 | 175 | 0.5711 | 0.7273 | 6.405 | 5.774 |
| 141 | 168 | 0.2174 | 0.5527 | 5.188 | 3.928 |
| 135 | 165 | 0.3574 | 0.5326 | 4.554 | 3.696 |
| 152 | 157 | 0.2177 | 0.7454 | 6.501 | 5.123 |
| 145 | 152 | 0.2397 | 0.6192 | 6.745 | 5.002 |
| 142 | 140 | 0.2894 | 0.7754 | 3.695 | 2.544 |
| 148 | 167 | 0.3078 | 0.6898 | 4.871 | 2.947 |
| 139 | 171 | 0.2165 | 0.7326 | 5.118 | 3.888 |
| 133 | 161 | 0.3208 | 0.8457 | 6.352 | 2.938 |
| 135 | 164 | 0.1005 | 0.5056 | 7.776 | 4.121 |
| 141 | 157 | 0.2484 | 0.7848 | 6.009 | 3.669 |
| 128 | 142 | 0.2056 | 0.6289 | 6.689 | 4.656 |
| 133 | 146 | 0.2701 | 0.6288 | 5.785 | 3.747 |

Table 6 Main details of 600 mm diameter steel pile tests

| SLT (ton) | DLT (ton) | Shaft Damping Ratio | Toe Damping Ratio | Shaft Quake (mm) | Toe Quake (mm) |
|---|---|---|---|---|---|
| 188 | 205 | 0.5942 | 0.8415 | 4.578 | 3.569 |
| 178 | 194 | 0.6954 | 0.8688 | 7.566 | 5.945 |
| 167 | 188 | 0.6367 | 0.5547 | 7.205 | 5.697 |
| 175 | 202 | 0.3295 | 0.5932 | 6.188 | 4.205 |
| 171 | 178 | 0.5158 | 0.9009 | 4.677 | 3.956 |
| 178 | 222 | 0.1932 | 0.6153 | 5.186 | 3.256 |
| 169 | 192 | 0.2236 | 0.5479 | 6.556 | 2.778 |
| 164 | 185 | 0.2268 | 1.0021 | 6.357 | 2.874 |
| 194 | 232 | 0.4107 | 0.8006 | 5.459 | 3.669 |
| 182 | 221 | 0.1919 | 0.7128 | 7.625 | 2.257 |

In the first point, the failure load is defined here as the intersection of SLT and DLT movement curve with the Davisson method line so that this load value must be well defined and represent the full skin or shaft resistance and a considerable portion of the end bearing resistance.

Also, from Fig. 3, the movement of failure load of SLT with Davisson method is 16.4 mm (4.1 % of Pile width) which gives an important fact that the failure load in this case equals to full shaft resistance in addition to the sensible portion of end bearing and this fact satisfied the idea of applying Davisson method in all piles of this paper. A final remark associated to first pint is focus on the permanent movement or plastic movement of the test which represent for PRC pile SLT (7.00/20.63=0.34) and for steel pile SLT (4.40/23.24=0.19) so that these magnitude are considered in further analyses for load net movement curve which has many applications in pile engineering and this subject is beyond the matter of current paper.

The second point of paper interesting is to be find the relationship between failure load using Davison Method which applied to both SLT and DLT as given in Table 3 associated with precast reinforced concrete pile and Tables (4 to 6) as connected to steel piles and these results are plotted in Figs. 5 and 6, respectively. As both Figs. 5 and 6 display the nature of failure load for both SLT and DLT which for precast reinforce concrete pile is:

$$DLT_{PRC} = 1.0334 \times SLT_{PRC} + 18.622 \qquad (2)$$

Which take the linear relationship coefficient of correlation ( R=0.9265), and for steel piles is:

$$DLT_{STL} = 1.0213 \times SLT_{STL} + 18.927 \qquad (3)$$

Which take the linear relationship coefficient of correlation ( R=0.9689).

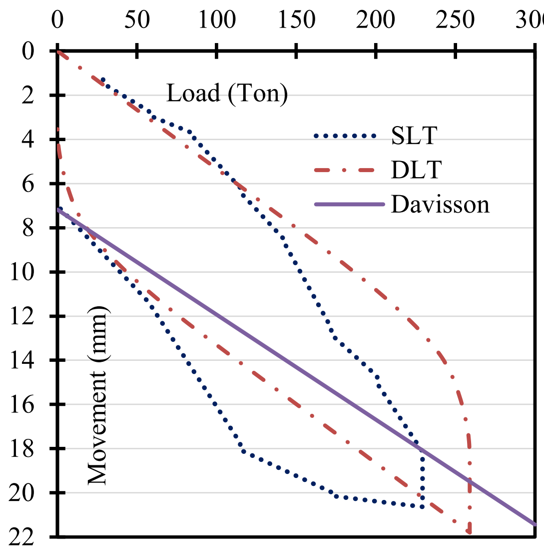


Fig. 3. Test load-Movement relationship of SLT, DLT, and Davisson method for PRC pile

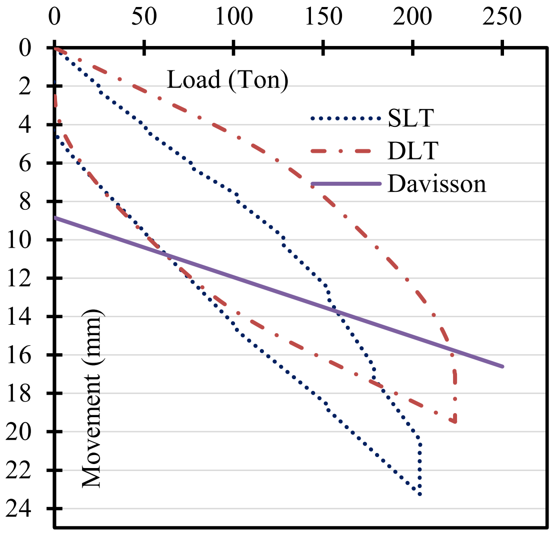


Fig. 4. Test load-Movement relationship of SLT, DLT, and Davisson method for 600 mm diameter steel pile

The last two equations give a n important facts which is a direct and strong relationship between SLT and DLT failure load determined by Davisson method with specific results that DLT is higher than SLT regardless pile type or pile size as indicate according to the assessment of Table 7 [17].This results can be explained by two reasons, the first one is connected to the method used for solving the wave theory in CAPWAP software which used by Smith solution in which this solution dropped the inertia term of dynamic equation of whole Hammer-Pile-Soil system while the second reason is related to the variation of soil properties (damping ratio and quake value) existence in the location of pile tests that demonstrated in the following paragraph.

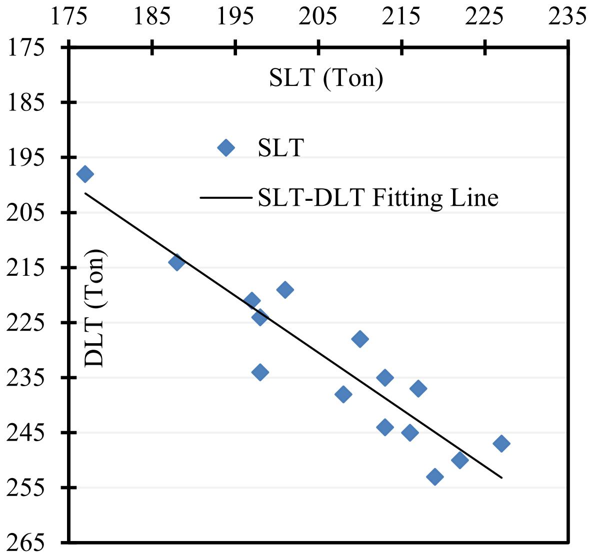


Fig. 5 SLT and DLT relationship for precast reinforced concrete PRC piles

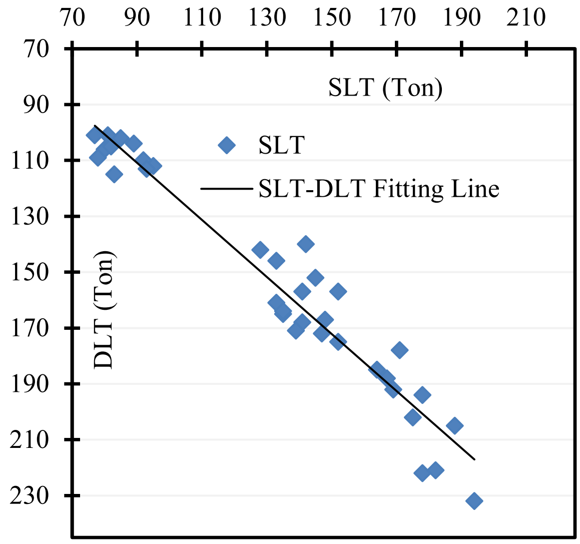


Fig. 6 SLT and DLT relationship for steel piles of diameters 400mm, 500, and 600mm

Table 7 Rule of Thumb for Interpreting the Size of a Correlation Coefficient [17]

| Size of Correlation | Interpretation |
|---|---|
| 0.90 to 1.00 (−0.90 to −1.00) | Very high positive (negative) correlation |
| 0.70 to 0.90 (−0.70 to −0.90) | High positive (negative) correlation |
| 0.50 to 0.70 (−0.50 to −0.70) | Moderate positive (negative) correlation |
| 0.30 to 0.50 (−0.30 to −0.50) | Low positive (negative) correlation |
| 0.00 to 0.30 (0.00 to −0.30) | negligible correlation |

As known, the output results for each hammer blows there are about 400 results that takes form of table, graph, or single values which put categories such as force, energy, displacement, and etc..in Table 8 Summary of SLT , DLT, and soil properties are given. The third point interesting in the current paper is related to the important soil parameters of DLT which are the damping and quake values for both the shaft and toe (tip pile point) of the tested piles. It is so clear that the SLT (failure load) is represent (85.2-90.0)% of test load while (98.0-106.2)% for DLT failure load and this results indicate an important mater that the magnitude of test load value can be increased by at least 10% for further pile test in future project in the Majnoon Oil Field.

The damping ratio or damping factor (Smith method) play an important role in determine the pile bearing capacity for which in Case Method which used assumed damping factor of soil near the pile toe, this assumed value depended on the soil type and for hard clay it takes value 0.7, while in CAPWAP method it used both the damping factor of shaft and damping factor of toe that both values will be separately found by CAPWAP program in order to reaching the Matching signal less than 4. Therefore, when the damping factor increases lead to decreasing the static pile capacity.

Table 8 Main characteristics of SLT, DLT, shaft damping, and quake value

| Term | Item | PRC400 | STL400 | STL500 | STL600 |
|---|---|---|---|---|---|
| Pile Section | | (400×400) mm | 400 mm Dia. | 500 mm Dia. | 600 mm Dia. |
| SLT (ton) | Ave. | 207 | 85 | 137 | 177 |
| | Stand . Dev. | 11.0 | 5.6 | 9.9 | 7.4 |
| | Load (%) | 90.0% | 85.2% | 85.5% | 88.3% |
| DLT (ton) | Ave. | 232 | 106 | 157 | 202 |
| | Stand . Dev. | 12.1 | 3.8 | 11.9 | 14.5 |
| | Load (%) | 101.1% | 106.3% | 98.0% | 101.0% |
| Shaft Damping Factor | Ave. | 0.4379 | 0.4362 | 0.3008 | 0.4018 |
| | Stand . Dev. | 0.1320 | 0.2025 | 0.0936 | 0.1688 |
| Quake Value | Ave. | 3.956 | 3.445 | 3.859 | 3.821 |
| | Stand . Dev. | 0.893 | 0.951 | 0.731 | 0.904 |

As seen in Table 8, the shaft damping factor values of tested piles is ranging from 0.3008 to 0.4379 (this value represent the average effect of all damping factor of soils lauder along the pile shaft) which is lesser than the Case Method Value which indicating that the CAPWAP method give a higher and accurate values of shaft resistance than Case Method . In other side, from Table 8, the toe damping factor values of tested piles is ranging from 0.6100 to 0.7629 which is round about the Case Method Value which indicating that the CAPWAP method may matching with closer and accurate values of toe resistance than Case Method. Moreover in Table 8, the shaft quake factor values of tested piles is ranging from 4.303 to 6.347 (this value represent the average effect of all quake factor of soils layer along the pile shaft) which is lesser in steel pile than the precast concrete pile and this results can be attributed to the larger friction occur between concrete pile and the surrounding soils and finally from Table 8, the toe quake value of tested piles is ranging from 3.445 to 3.956 which is larger than the default value (2.540 mm) recommended by

Case Method Value and the dynamic formula which indicating that the CAPWAP method may matching with bigger values of toe quake leading to more economic driving criteria than the usual dynamic formula which used in most pile engineering projects by 40%. The above output results can be illustrating as follows:

The variation of toe damping factor from the soil investigation report (hard clay soil) can be explained from the historical geology of soil in the Majnoon Oil field that this soil is virgin and non constructing structures had been built during the past in this area or zone (normally consolation clay soil type). Also, it has been notice during the driving log recorder for many piles that there is a single thin thickness strong layer of varying thickness (0.25 m to 0.75 m) lying at depth 17.0 m which causes of these differences in shaft larger than in toe damping factor.

## 5. CONCLUSION

The output results of 100 pile tests can be summarized as in the following points:

DLT and SLT were successfully used to check, estimate, and verify the design the foundation pile capacity using precast reinforced concrete pile and steel piles in Majnon oil field. Both test types were assessment by Davisson method to calculate the failure load in which the failure load represent the full shaft resistance and a considerable portion of the end bearing capacity. A very strong linear relationship was found between SLT and DLT (using CAPWAP software) for both pile types with regression data analysis. Damping factor calculated by CAPWAP software is closer to the value recommended by the soil investigation report for toe zone but its value is far away in shaft zone if the analysis was done using the CASE method. the toe quake value of tested piles is larger than the recommended value of the dynamic formula by 40% which mean the DLT can be lead to more safe and economic construction for further project

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