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THE SOUTHERN INSTITUTE OF WATER RESOURCES RESEARCH

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STUDY ON THE EFFECTS OF STATIC AND DYNAMIC LOADS ON BEARING CAPACITY OF THE PILE IN HO CHI MINH CITY

SUMMARY OF THE DOCTORAL THESIS

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INTRODUCTION

1. The urgency of the research topic.

Ho Chi Minh City (HCMC) concentrates many civil and industrial constructions. However, this area is located on soft soil with poor load capacity, especially with dynamic loads. In industrial zones, locating machine foundations to withstand dynamic loads of different frequencies, amplitudes and intensity. The above loads from the structure transmitted to the pile, or from the surrounding ground affect the pile causing the pile itself, the extreme deformation zone around the pile has different effects. Research to calculate the dynamic load capacity of the pile foundation supporting the project as well as find out the decrease in load capacity after the project is under dynamic load is now necessary. The calculation of the effect of dynamic load on the pile load has many methods but dispersion results. The static test method is reliable but costly and time consuming and has no results on the effect of dynamic loads on the pile load. To add to the effect of dynamic load on the pile load capacity is multiplied by the coefficient on the static load capacity of the pile. The construction of experimental models to determine the foundation pile calculation parameters of the foundation soil has actually been proven to simulate well the pile operations in the ground. Through the analysis and comparison of the pile static compression test results and simulation with different dynamic parameters, find out the parameters of the ground to simulate the stress - deformation state of the pile and the behavior of the ground around the pile there is plastic deformation.

2. The purpose of the thesis.

Study on simulation of static compression test to find out suitable soil model and select reasonable parameters. Consider applying suitable soil model to study stress path with different properties and conditions of the soil. Selecting the modeling parameters of the ground to simulate the stress - deformation state of the pile and the soil behavior in the area with plastic deformation around the pile. Research engineering geology, hydrogeology and analyzing and evaluating the ability to affect the load capacity under dynamic load in the area. Research and build a small-scale physical model, conduct dynamic load tests on piles to determine the effect of dynamic loads on the load capacity and settlement of the pile. Analyze the dynamic behavior of the pile when subjected to dynamic loads at different frequencies. Study the effects of the ratio L/D, the effect of pile - foundation, consider the immediate load capacity under dynamic loads. Set the correlations Force - Deflection, Force - Bow resistance, Force - Ratio of Side resistance / tip resistance in the pile under dynamic load on the sandy soil of HCMC.

3. Object and scope of the research

- Object of the thesis is the right center compression pile influenced by dynamic load in the sandy environment.

- Scope of the study: The above multi-layered area is the clay and clay layers with poor load capacity, the sand layers below are selected to place the piles in this range. Therefore, the dissertation's research focuses on the effect of dynamic load on the pile in the medium compact sandy soil layer in the area of HCMC. This is a popular soil layer and is rated to be quite good under static load. From there, it is necessary to study the pile when under dynamic load will be reduced and the effects of friction for the pile section in this soil layer on the pile load capacity. Study of single pile bearing vertical axial load. The experimental model uses absolute hard pile to eliminate all effects of load distribution and measurement results. The effects of the pile-to-pile connection were ignored and not examined in the study. The load acting on the foundation is the cyclic load. The research frequency to influence is the frequency of stimulation that causes mechanical responses, not to the response frequency of the pile - pile station system.

4. Research content

Overview of calculation methods affecting static and dynamic loads on pile load capacity according to field experiments and other studies in the world. Research and application of numerical methods in the analysis and calculation the load capacity of pile. Select the suitable model with the static compression test results to simulate finding the destructive load. Research and manufacture a physical model to determine the effect of dynamic load on pile load capacity. The test determines the influence of dynamic load on load capacity of pile. Investigating the mechanism of longitudinal force distribution in the pile body, subsequent stress changes are mobilized between the pile wall and soil according to frequency. Analyze the influence of dynamic load on pile dynamic behavior, establish stress, strain and frequency correlations on pile types with different L/D.

5. Approach and methodology

Statistical methods: Collect, analyze, and synthesize research results. Statistical processing, analyzing experimental results, establishing correlations with modern data processing software. Experimental methods: Experimental research to conduct experiments on physical models in the room to serve as a basis for comparative analysis and comparison of results. Numerical simulation method: Research on simulating static compression test using Plaxis software for comparative analysis. Using data processing software to find results between numerical simulations and field experiments find out correlations in the ground model.

6. The new contributions of the thesis

1) Constructing a static pile test model to study the effects of physical parameters on the load capacity of pile under static load and decrease when subjected to dynamic loads with the sand foundation. From there, studying the effects of the dynamic parameters on stress - strain, load capacity of pile and find the correlations.

2) Propose the settlement-frequency correlation equations for pile with smooth surface, pile with rough surface. Correlation equations between Force - Unit friction - Tip resistance, Force - Ratio Fs0 / tip resistance, Force - Ratio of Fs1 / tip resistance for different L/D piles.

3) Perform simulations of static compression experiments to find out MCC (Modified CamClay) model with the closest results compared with static compression test results. The study shows that the parameters most strongly affect the simulation results of static compression test. Using the MCC model to simulate the destructive compression to find the extreme load capacity of the pile.

4) Proposing correlation coefficients in static compression test λ/κ in cycle 1, cycle 2 and general correlation λ/κ in both cycles. The correlation equations M, Lambda, Kappa in the MCC model of Plaxis software in the simulation of the static compression test to determine the load capacity of pile.

7. Scientific and practical significance

The thesis initially contributes to clarify the effects of dynamic and static loads through simulation of static compression experiments as well as small-scale physical model experiments. Thereby proposing correlation equations between frequency and settlement, force and strain, force and resistance relationship.

The results of the study provide data to serve as a basis for analyzing the impact of dynamic loads in the design of pile load capacity considering the effect of dynamic loads that may appear in HCMC construction conditions.

CHAPTER 1.

OVERVIEW STUDY ON THE EFFECTS OF DYNAMIC LOADS ON BEARING CAPACITY OF PILE.

1.1. Problem.

1.2. Study the effects of dynamic loads.

1.3. Shear resistance characteristics under the influence of impulse load.

1.4. Strength, deformation under the influence of impulse load.

Casagrande and Shannon experimented with impulse loads: t_L= 0.2s.

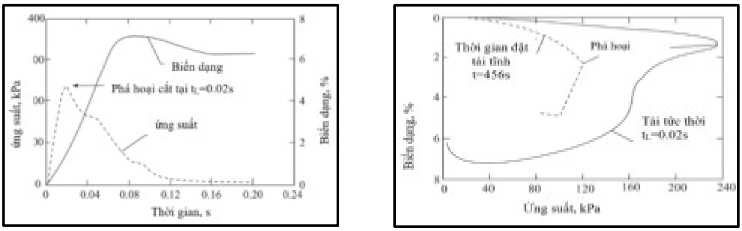


Figure 1.11: Stress - Deformation of soil in test with impulse load.

1.5. Study of foundation vibration with dynamic characteristics of the foundation impacting on the ground.

1.6. Research related to the research direction of the topic.

According to Han (2018) researched the experimental model of the pile site to find the load capacity and stored stress in the pile. According to Naggar (2019) research to establish a stress wave energy propagation model in semispace. The simulation results for the pile are compared with reference software for frequency effects with different physical effects.

1.7. Study on calculating load capacity by finite element method.

According to Wu (2020), Tolun (2020), Rajpoot (2020), Lin (2020) simulated the number of different models for the pile to study the dynamic response of the foundation. Ahmed (2015) simulated research on the influence of pile - soil on dynamic response of pile under dynamic load. Azizkandi (2018), Chaudhuri (2020), Zhang (2020), Lou (2020), Yan (2016), Liu (2020), Zhu (2020), the authors have focused on simulating the number of dynamic load effects and found quite reasonable results for the research direction of numerical simulation.

1.8. Research on experimental model of small scale for pile under dynamic load.

Garala (2020) studied experimental model of aluminum pile centrifugation. Rui He (2019) studies the dynamic wind turbine single pile model with different frequencies. Huang (2020), Mishra (2019), Li (2020), Subramanya (2019), Varghese (2020), Zhanfang (2020), Yi (2017), Zhou (2019), researching the design of models under dynamic load.

1.9. Conclusion

1. The study of the effect of dynamic load in addition to static load on the pile foundation in the area should be considered when designing the foundation. The formulas for determining the settlement of the foundation have not considered all the parameters affecting the roughness, the L/D ratio, and soil mechanical properties ... When the deformation rate increases, according to Caroll: C_u (dynamic)/ C_u (static)= 1.5. When the strain rate increases, it corresponds to the decrease in the internal friction angle of the soil, φ'(dynamic) = φ'(static) - 2^0.

2. The formula of Braja M. Das (2011) has added the following parameters: Frequency of dynamic load, Circulating force Q, Elastic stiffness k of foundation system. Ahmed (2015) has not yet calculated the effect of damping compared to pile length in soil. When calculating the dynamic load capacity of piles from the load capacity of single piles, taking into account the effect of dynamic loads, the provisions of the Vietnamese construction standards do not provide enough information to apply.

3. Influence of dynamic loads in civil, industrial, bridge and road constructions, with different frequencies, amplitudes, and intensity, causes different responses to the pile-foundation system. The above load from the project transmitted to the pile, or from the surrounding ground affects the pile causing the pile itself, the extreme deformation area around the pile under different circumstances in the specific area ground is also required. Research by simulating the number of static compression tests and testing of the pile model under dynamic load can partly meet the requirements.

CHAPTER 2
RESEARCH ON APPLYING NUMBER METHOD IN ANALYSIS AND CALCULATION OF PILE LOADING.

2.1. Question.

Combining the semi-empirical formula of the foundation construction unit, field experiment, and numerical simulation is a research direction with scientific and practical value in calculating pile load capacity through assessment analysis stress - deformation of the foundation under the pile foundation using Plaxis software with foundation models. Stress-strain analysis of the deep foundation soil through simulation of pile static compression test with a stress-strain probe attached to the pile body when reverse analysis of the experiment to find out the ground parameters consistent with the compression results static.

2.2. Overview of load capacity by static compression test.

2.3. Study on static compression test of pile on works in HCMC area.

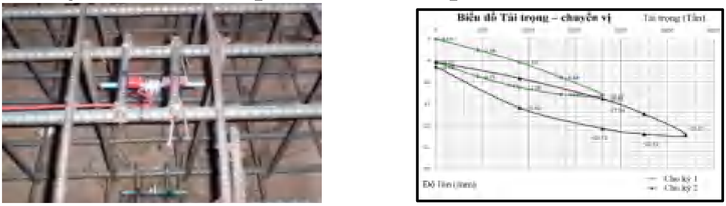


Figure 2. 1: Experiment and histogram of Load Test results

2.4. Calculate the load capacity based on the static compression test results.

$S = \xi.S_{gh}$. $S = \xi.S_{gh} = 0{,}2x80=16mm.$

2.5. Study on simulation of static compression test to determine the load capacity in Plaxis.

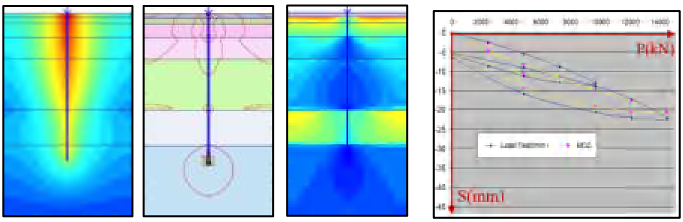


Figure 2. 10: MCC simulation results with LoadTest

2.6. Study on simulation of static compression test to determine the load capacity in Plaxis.

2.6.1 Establish model parameter correlation

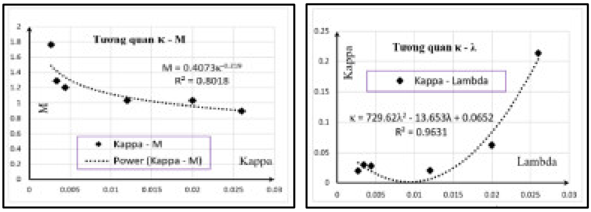


Figure 2. 24: Graph representing parameters κ - λ

The results of correlation of parameters in the MCC model:

M-Kappa: $M = 0.4073\kappa^{-0.219}$; Lambda-Kappa: $\kappa = 729.62\lambda^2 - 13.653\lambda + 0.0652$

2.6.2 Analyzing and comparing calculation results by MCC model and static compression test.

2.7. Study on simulation of destructive compression of 250% P_{TK}.

2.8. Simulation study of experiment to find load capacity according to conventional limit displacement.

2.9. Conclusion

1) The MCC model is suitable for soil models developed recently for foundation computation software. The analysis of the MCC model while using Plaxis software combined with comparing the static compression test results is the basis of accurate assessment of strain stress in the soil.

2) According to the experimental results, there is $\lambda / \kappa = 13.12 / 5.41 = 2.4$ (CK1) and $\lambda / \kappa = 22.2 / 6.49 = 3.4$ (CK2), $\lambda / \kappa \sim 3$ correlation.

3) M – Kappa correlation: $M = 0.4073\kappa^{-0.219}$

4) Lambda - Kappa correlation: $\kappa = 729.62\lambda^2 - 13.653\lambda + 0.0652$

CHAPTER 3.

RESEARCH FOR DESIGNING PHYSICAL MODEL FOR DETERMINING THE EFFECTS OF DYNAMIC LOADS ON BEARING CAPACITY OF PILE.

3.1. The problem of the model experiment.

The research model considers the effects of the load on the stress – Deformation along the length of the pile body and the pile tip, simulates customizable changes of many factors affecting static and dynamic loads on the load capacity of pile.

3.2. Dimension analysis.

According to the research and proven fact, the frequency *f* has a decisive influence on the displacement of the pile: $f = g(L; D; \gamma; \varphi; c; d)$

Transform Pi equation $$g\left\{\frac{L}{D};\ \frac{d}{D};\ \varphi;\ \frac{c.f}{\gamma^{1/2}}\right\} = 0$$

Research parameters from 7 independent quantities after transforming Pi to 4 dependent quantities. The dependence and relationship between the quantities shows the level and importance of the quantities with the parameters of the dynamics due to the external dynamic loads acting on the settlement and displacement of the pile.

3.3. Requirements on similar models.

3.4. Advantages and disadvantages of small-scale physical models.

3.5. Model implementation

3.6. Material selection and model scale.

3.7. Analysis of limit load capacity of the pile.

3.8. Stress transmission mechanism.

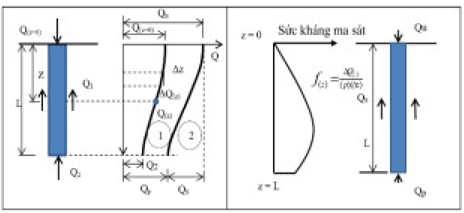


Figure 3.1: Stress transmission mechanism and Mobilization resistance.

3.9. Equation for determining the load capacity of the pile.

$Q_u = Q_s + Q_p$. Straingauge longitudinal force i: $P_i = \Delta\mu\varepsilon_i$ x EA.

3.10. Study force distribution in the pile according to field test results.

3.11. Pile research used in experimental models.

Figure 3. 2. Straingage, Smooth pile, rough pile.

3.12. React system

3.13. Load measuring equipment.

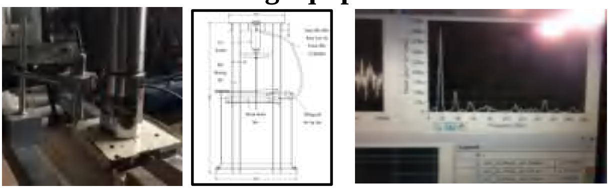
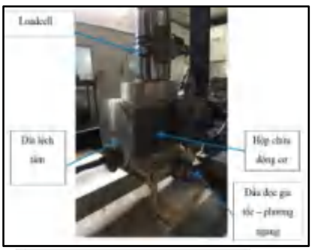
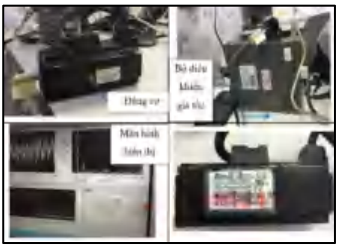


Figure 3. 2: Signal processors fordevices and connections

3.14. Dynamic Load System.





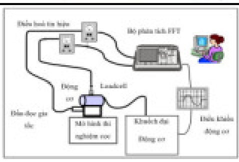


Figure 3. 4: Installation diagram of model experimental equipment system

3.15. Sequence of experimental steps on the model.

3.15.1. Compress the soil in the barrel.

3.15.2. Sequence of compaction of soil samples in barrel

3.15.3. Pile installing process.

Figure 3: 5: Pile installing process – Checking the verticality and conducting pressing

3.15.4. Pile static compression.

Conduct static compression to determine the ultimate load capacity and maximum bearing capacity. Connect strain gauges, load cells to the data reader.

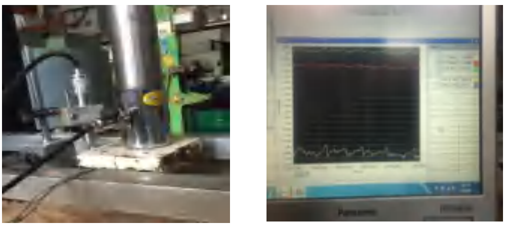


Figure 3. 6: Static compression test of piles, the screen displays the results.

Figure 3. 7: Signal processor connecting accelerometer and transducer

3.16. Conclusion

1) Experiments on small-scale physical models can ensure compatibility conditions as well as reduce costs. Meanwhile it is possible to increase the options for input parameters compared to large scale field experiments. Studying the effects of soil mechanical properties, the ratio of L/D on settlement, displacement and pile load capacity is enough to ensure a suitable experiment.

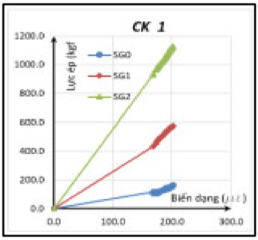
2) The study conducted experiments on the influence of geometrical parameters of pile L/D, soil mechanical properties c, γ, dynamic parameters due to external dynamic load on settlement and displacement The position of the pile ensures the reduction of test parameters but still has acceptable results at the allowable level. Studies to design the modeled structure system ensure the ratio problem and pile-soil interaction problems.

3) Research, design and install the system of testing equipment to measure the effect of dynamic load on pile behavior, load capacity enough to ensure that the experiment meets the set standards and objectives. After conducting with static pile, let the pile rest at the right time, conducting dynamic test on the pile to study the behavior of the pile.

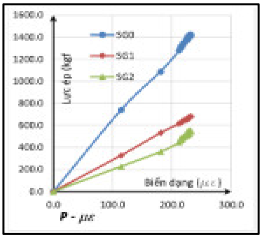
CHAPTER 4.

EXPERIMENTAL DETERMINATION OF THE EFFECTS OF DYNAMIC LOADS ON BEARING CAPACITY OF PILE.

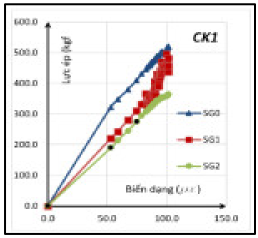
4.1. Static compression test results on pile L40.



Pile L40



Pile L50



Pile L60

4.2. Measurement result of pile L50.

4.3. The results of measuring the L60 pile at cycle 1 and cycle 2.

4.4. Dynamic load testing on piles.

Dynamic parameters are loaded on the speed control software.

Figure 4. 9: Frequency correlation between control and accelerometer

4.5. The results of the dynamic test on the pile-behavior of the pile.

4.5.1 The results on the rough L40 - rough pile

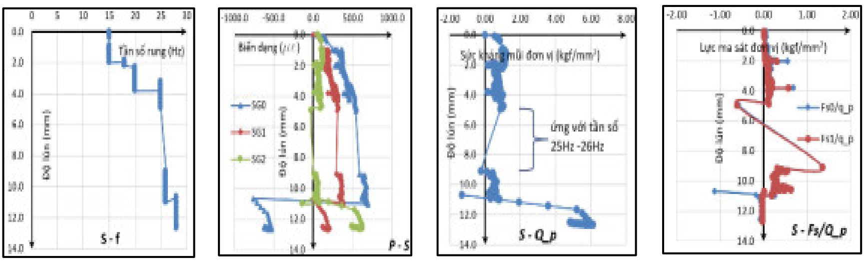


Figure 4. 13: Frequency - Settlement - Resistance of L40 pile

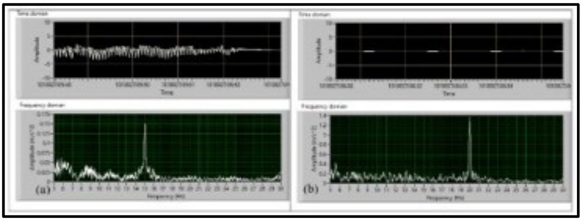


Figure 4. 17: The results of frequency analysis FFT of smooth L40 pile

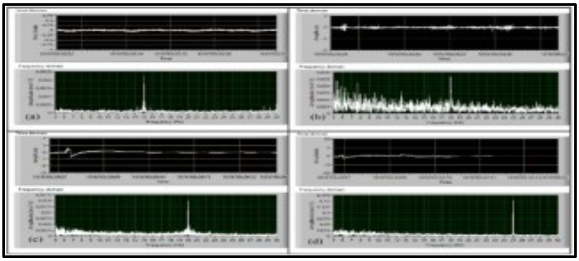


Figure 4. 15: The results of the FFT frequency analysis of rough L40 pile

4.5.2 Results on L50 - rough pile

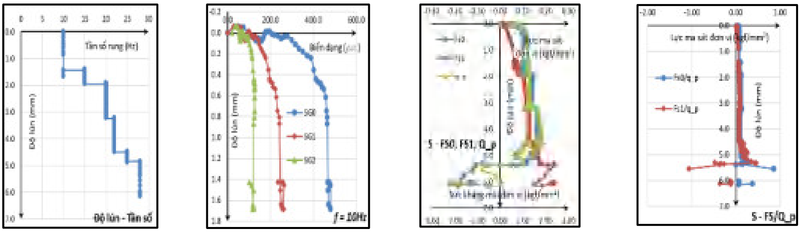


Figure 4. 19: Diagram of Settlement – Frequency – Resistance L50

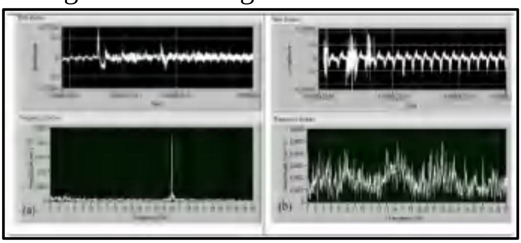


Figure 4. 26: FFT analysis results of smooth pile L50 at failure frequency.

4.5.3 Results on rough L60 - rough pile

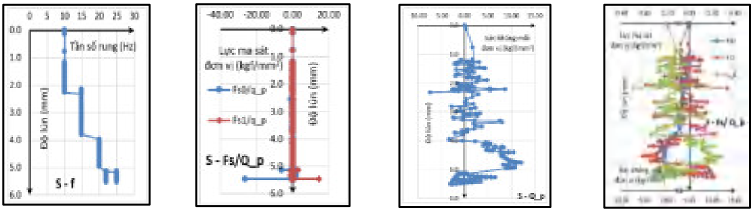


Figure 4. 29: Diagram of Settlement – Deformation of pile L60 rough

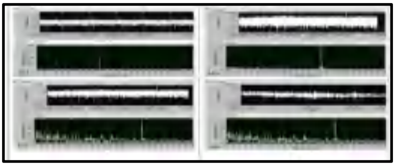


Figure 4. 33: FFT frequency analysis results of rough L60 pile

4.5.4 Result on L60 - smooth pile

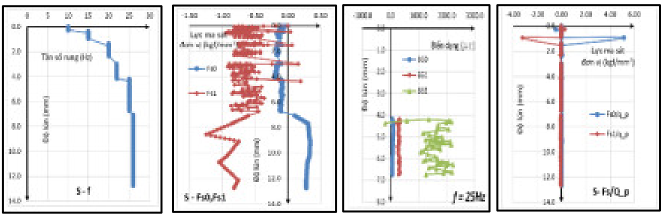


Figure 4. 34: Table Settlement - smooth L60 pile resistance

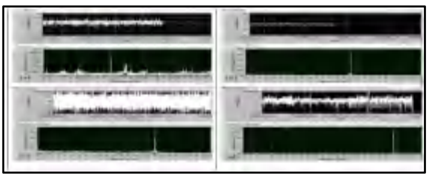


Figure 4. 38: Results of FFT frequency analysis of smooth L60 pile

4.6. Some experimental images.

4.7. Conclusion

1) The relationship between the settlement - the ratio of unit friction force and the tip resistance shows that the relative ratio is homogeneous during the compression test. The ratio Fs0/q_p shows a very large distribution of lateral resistance near the top of the pile. However, with the ratio Fs1/q_p, the distribution for lateral resistance near the pile tip is relatively small. Formation development, distribution, redistribution of resistance along the pile length with different L/D are considered. With L/D> 25, the pile appears bending moment, causing local damage and overall damage along the pile body at the position with great internal force.

2) Studying the effect of frequency on piles shows that: When testing the static compression, the pile load capacity tends to decrease. The reduced load capacity is due to a number of reasons such as longitudinal bending rather than a drop in the pile and lead to failure. According to many studies have proven, when the pile is long leading to slant, bending, breaking, affecting the settlement, the load capacity.

3) Researching the pile types with different L/D and roughness helps researcher have an overview of the pile load capacity under static and dynamic loads. The relationship of the settlement of the pile with different frequencies; Settlement - Deformation value; Relation of Settlement - Unit tip resistance - Unit side friction; The relationship of Settlement - The ratio of the unit friction force and the tip resistance to the different pile depth shows that with a specific frequency, the ratio L/D will have the most significant influence on the load capacity.

4) Frequency from 22Hz to 28Hz, the absolute high value distortion describes the behavior when subjected to oscillation frequencies. The displacement through the equilibrium position of the pile station increases rapidly leading to lateral friction failure.

5) For rough L50 pile, plot strain value at the pile head position (SG0) is large, compression strain increases sharply. L50 Pile is smooth, Settlement -

Unit tip resistance starts to decline and changes sign of resistance at 28Hz when settlement does not increase. Compared with the rough piles, at the settlement of 6 mm, there is the phenomenon of impression change. Correlation of settlement and lateral friction of two types Smooth - Rough are equivalent.

6) The results of frequency spectrum analysis of smooth piles have a very fast peak acceleration compared to the rough pile. The analyzed intensity of variation on the time domain of smooth L60 pile changes drastically, corresponding to an increase of 4 times compared to that of rough pile L60.

CHAPTER 5
ANALYSIS OF THE TEST RESULTS RESEARCH APPLIED TO REALITY.

5.1. The relationship of deformation of pile resistance to frequency.

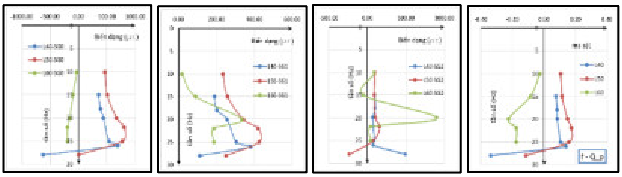


Figure 5. 1: Diagram of Frequency - Distortion - Tip Resistance Q_p.

5.2. Comparing test results of different L/D piles

5.3. Comparing test results of piles with different roughness

5.4. Comparing the relationship Settlement - Frequency of smooth piles

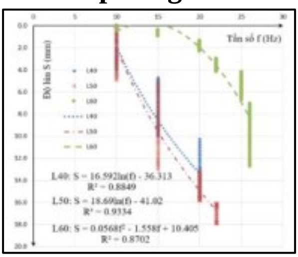


Figure 5. 12: Settlement correlation graph - Frequency (smooth piles)

Table 5. 1: The equation correlates subsidence - frequency smooth piles

No.	L / D	Correlation equation
1	20	*S = 16.592ln(f) - 36 313.*
2	25	*S = 18.69ln (f) - 41.02.*
3	30	*S = 0.0568f2 - 1.558f + 10.405.*

5.5. Comparing relationships subsidence - Frequency piles rough

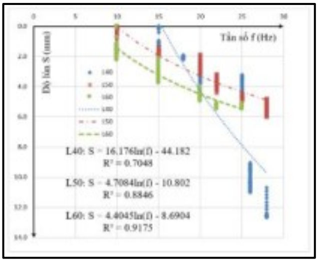


Figure 5. 13: Graph correlation subsidence - Frequency (pile rough)

Table 5. 2: The equation correlates subsidence - Frequency rough pile

No.	L / D	Correlation equation
1	20	S = 16.176ln (f) - 44.182
2	25	S = 4.7084ln (f) - 10.802
3	30	S = 4.4045ln (f) - 8.6904

5.6. Study Force - Deformation of pile under frequency destructive.

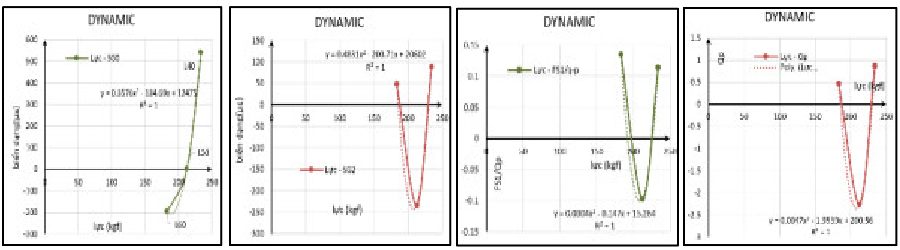


Figure 5. 14: Results of Force - Deformation of pile at destructive frequency

5.7. Analysis of stress path of soil under dynamic load.

5.8. Calculating and applying research results to piles in practice.

5.8.1. The calculation parameters for piles in reality

5.8.2. Set the actual ratio for Settlement - Frequency smooth pile.

Table 5. 4: Settlement equation - Actual smooth pile frequency

No	L/D	Correlation equation
1	20	$S = 0.66\ln f - 2.51$
2	25	$S = 0.75\ln f - 2.5$
3	30	$S = 0.0009f^2 – 0.012f + 0.416$

5.8.3. Set real ratio for Settlement - Frequency correlation of the rough pile.

Table 5. 5: Settlement equation - Actual abrasive pile frequency

No	L/D	Correlation equation
1	20	$S = 0.65\ln f - 2.81$
2	25	$S = 0.19\ln f - 0.73$
3	30	$S = 0.17\ln f - 0.62$

5.8.4. Result of force and deformation along pile body when sabotage.

5.8.5. Correlation equation at the actual failure frequency

Table 5. 3: Correlation equation at the actual failure frequency

No	Location	Correlation equation
Force - Deformation		
1	SG0	$S = 223.5P^2 – 84181.25P + 12475.$
2	SG1	$S = 4.625\ P^2 – 459.44P + 71.857.$
3	SG2	$S = 301.94\ P^2 – 125443.75P + 20602$
Friction resistance - Force		

4	FS0	$F = 0.125\ P^2 – 38.187P + 5.6599$
5	FS1	$F = -0.125\ P^2 + 57.062P - 9.3687$
6	Q_p	$F = 2.937\ P^2 – 1221.18P + 200.56$
Force - percentage of resistance party /tip resistance		
7	Top pile	$FS0/Q\_p = -0.125\ P^2 + 63.56P - 11.608$
8	Tip pile	$FS1/Q\_p = 0.25\ P^2 – 91.875P + 15.264$

5.9. Conclusions

Research results show that at different positions stress - deformation along the pile body change markedly with different types of piles with different L/D. The graph is based on the data of the piles L40, L50, L60, the selected results are taken at the time of settlement 6mm at the time of the pile failure to compare, analyze and find the correlations.

1) Study the relationship of the settlement of piles with different frequencies; Settlement - deformation value; Relation of settlement - unit tip resistance - unit side friction; The relationship of Settlement - The ratio of the unit friction force and the tip resistance to the different pile depth shows that with a specific frequency, the ratio L/D will have the most significant influence on the load capacity.

2) Pile L40, starting at 26Hz, Q_p value is strongly reduced. At 28Hz, the response of the tip to the frequency makes the tip resistance increase dramatically. The compressive force coincides with the stress wave causes the resistance to increase strongly by the failure mechanism of the pile tip. Pile L50 has quite stable Q_p and loses its load capacity at settlement S = 5mm.

3) With starting frequencies of 15Hz to 20Hz, the distortion of the pile body straingages and the tip of the pile has small fluctuations, the distortion near the pile station has large value variation. From 22Hz to 28Hz, the absolute high value distortion describes the behavior when subjected to oscillation frequencies. Movement through the equilibrium position of the pile station increases rapidly leading to lateral friction failure.

4) Throughout the length of the pile, the analysis found the relationship Force - unit friction - tip resistance as well as the relationship between force - FS0 ratio / tip resistance, force relationship - ratio FS1 / tip resistance to Allometric equations are set up in chapter 5 of the thesis.

5) Pile with L / D of 20 or more, with prototype D400mm, scale 1/25, frequency with scale factor $(1/25)^{-1/2}$ (ratio = 5). With the frequency range from 22Hz to 28Hz, the average is 25Hz, the pile with L/D> 20 internal force reaches dangerous value, the settlement increases rapidly, the pile ground load capacity drops sharply. It can be speculated that the frequency of about 5Hz can cause the pile L/D = 20 to sink into the ground, the reinforced concrete pile connections may be damaged.

CONCLUSIONS AND RECOMMENDATION

1. Conclusions

1) The Modified CamClay model can describe the foudation – pile responde reaches the destructive load with the basic set of parameters M, λ, κ. Within the survey problem range with $\lambda = 2{,}4\kappa$ (CK1); $\lambda = 3{,}4\kappa$ (CK2) và $\lambda/\kappa \approx 3$. For reference purposes when analyzing the calculation of similar problems, researcher proposes correlation: $M = 0{,}407\kappa^{-0{,}219}$.

2) From the dynamic load experiment on the scale model, obtained some remarkable results:

a) Frequency of the cyclic load has a decisive influence on the bearing capacity of the pile.

b) The slenderness L/D of the pile has a great influence on the dynamic load capacity of the pile. With the frequency range from 22Hz to 28Hz, the average is 25Hz, the pile with L/D>20 internal force reaches the dangerous value, the settlement increases rapidly, the pile ground load capacity drops sharply. It can be speculated that the frequency of about 5Hz can cause the pile L/D = 20 to sink into the ground, the reinforced concrete pile connections may be damaged.

c) The researcher proposes the relationship between the settlement of the pile and the frequency of cyclic dynamic load impacting on the pile:

❖ The side of the pile is smooth:

- (L/D = 20) is $S = 0.66\ln f - 2.51$
- (L/D = 25) is $S = 0.75\ln f - 2.5$
- (L/D = 30) is $S = 0.0009f^2 - 0.012f + 0.416$

❖ The side of the pile is rough:

- (L/D = 20) is $S = 0.65\ln f - 2.81$
- (L/D = 25) is $S = 0.19\ln f – 0.73$
- (L/D = 30) is $S = 0.17\ln f – 0.62$

2. Recommendations

1) The experiment was conducted only considering the condition of the free pile head without the presence of the pile, so it is not considered whether the mounting condition reduces the reduction of pile foundation load.

2) The proposed correlation with only a limited number of experiments may not be highly accurate, so it is necessary to use certain verification when used.

LIST OF PUBLISHED SCIENTIFIC WORKS

1. Nguyen Manh Tuong (2019), "Analysis of dynamic response of piles under dynamic load in Ho Chi Minh City area*"*, *Vietnam Journal of Construction.*

2. Nguyen Manh Tuong (2019), "Analysis of theoretical basis and calculation of pile bearing capacity through dynamic experiments on soft ground in the South*"*, *Vietnam Journal of Construction.*

3. Chau Ngoc An, Nguyen Manh Tuong (2020), " Research overview of dynamic loads and their effects on different soil*" Collection of results for Science and Technology* - *Southern Institute of Water Resources Research.*

4. Chau Ngoc An, Nguyen Manh Tuong (2020)," Physical geotechnical modeling – studying and designing physical models to study the dynamic response of piles under dynamic loads *"Collection of results for Science and Technology* - *Southern Institute of Water Resources Research.*