

CONTENTS

	Page
Abstract in Thai.....	iv
Abstract in English.....	v
Acknowledgments.....	vi
Contents.....	vii
List of Tables.....	x
List of Figures.....	xi
CHAPTER 1 INTRODUCTION	1
1.1 Introduction.....	1
1.2 Statement of Research.....	3
1.3 Purpose of The Research Works.....	3
1.4 The Scope of the Research Works	4
CHAPTER 2 LITERATURE REVIEW	5
2.1 Soil Improvement.....	5
2.1.1 Soft Clay	5
2.1.2 The Basic Compression Theory to Improve Soft Soil	6
2.1.3 The Fundamentals of Consolidation	7
2.1.4 The Primary Consolidation (Terzaghi theory)	9
2.2 Compact Vacuum Consolidation Method.....	10
2.2.1 Introduce Vacuum Method	10
2.2.2 Mechanisms Vacuum Preloading Method	13
2.3 Recent Studies on Compact Vacuum Consolidation (CVC)	16
2.4 The Techniques of Vacuum Preloading Method	17
2.5 Degree of Consolidation (DOC)	18
2.5.1 Calculate Degree of Consolidation by The Settlement (Terzaghi).....	18
2.5.2 Yoshikuni 's Method (1979).....	21

2.5.4	Car-rillo Theory to Calculate DOC	22
2.5.5	Asaoka (Empirical Method)	23
2.5.6	Degree of Consolidation Based on Pore Water Pressure	24
2.6	Laboratory Test.....	25
2.7	Field Test Results	26
2.8	Numerical Method	26
2.8.1	Three-Dimensional Finite-Element Analysis	28
2.8.2	Two-Dimensional Plane Strain Finite-Element Analysis.....	28
2.8.3	One - D Finite-Element Analysis	30
CHAPTER 3 RESEARCH METHODOLOGY.....		32
3.1	Introduction	32
3.2	Simulation Vacuum Preloading Method by Tri-Axial Apparatus.....	32
3.3	Tri-axial Apparatus.....	33
3.4	Prediction of DOC of Vacuum Preloading Method	35
3.4.1	Field Monitoring and Instrumentation.....	35
3.4.2	Asaoka Method.....	37
CHAPTER 4 RESEARCH AND ANALYSIS		39
4.1	Finite Element Method of Analysis for Drainage Boundary Condition Analysis	39
4.1.1	The Theory of Axisymmetric Consolidation.....	39
4.1.2	Solution for Axisymmetric Unit Cell under Vacuum Pressure	41
4.2	Solution for Axisymmetric Unit Cell under Vacuum Combine Surcharge Loading.....	46
4.3	Simulation in Laboratory Test.....	52
4.3.1	Soil Specimen	52
4.3.2	Test Procedure to control the instability of soil specimen under vacuum preloading	53
4.3.3	Test Results and Analysis.....	57
4.4	Summary Conclusions.....	61

4.5 Case study of Vacuum Consolidation at Nakhorn Sri Thammarat
Air port.63

4.5.1 Site Description63

4.5.2 Soil Conditions64

4.5.3 Construction and Field Monitoring Work of Vacuum
Preloading Method67

4.5.4 Behavior and Performance of Vacuum Consolidation Method.....70

4.5.5 Summary Conclusions.....77

CHAPTER 5 CONCLUSIONS AND DISCUSSIONS79

5.1 Research Conclusions.....79

5.1.1 The Gain of the Research79

5.1.2 The Advantages of Using the Vacuum Preloading Method80

5.1.3 The Factors Effect on Effectiveness of This Method81

5.2 Limitations of the Study:81

REFERENCES83

BIBLIOGRAPHY86

APPENDIX87

LIST OF TABLES

	Page
Table 2.1. Mechanism of consolidation of soil	8
Table 2.2: The effective of vacuum-preloading method	11
Table 2.3. Equivalent diameter (d_w) of PVD	20
Table 2.4. The period method to define the DOC	23
Table 3.1. List of functions and frequency of field instrumentation.	36
Table 4.1. The case studies for axisymmetric unit cell.....	43
Table 4.2. The ratio of Time factor	46
Table 4.3. The ratio of time factor for $n=20$, Vacuum combine surcharge	50
Table 4.4. Kasaoka clay's properties.....	52
Table 4.5. Parameter in vacuum proceed by tri-axial apparatus ($U=10\%$)	56
Table 4.6. Parameter analysis in vacuum proceed.....	57
Table 4.7. The data of vacuum procedure simulation to control instability of soil.....	58
Table 4.8. Summary of field investigations in soft soil.....	64
Table 4.9. Summary Index and Engineering Properties of soil at depth 0.00-4.00m..	65
Table 4.10. The lists and nos of field instrumentation works.....	69
Table 4.11. The stage of embankment filling period and vacuum operation	76
Table 4.12. Degree of consolidation and rate of settlement	76

LIST OF FIGURES

	Page
Figure 1.1. Layout of the Chevron Air Terminal	1
Figure 1.2. Layout of the project	2
Figure 2.1. The Sharp of settlement of soil clay.....	6
Figure 2.2. Principal of consolidation	7
Figure 2.3. One-dimensional settlement calculation (a) is for Eq. 2.5);.....	10
Figure 2.4. Air water separation vacuum pump system (et al. 2004).....	12
Figure 2.5. The lateral movement of soil due to by vacuum preloading	13
Figure 2.6. The mechanisms vacuum preloading method	14
Figure 2.7. The consolidation process	15
Figure 2.8. The stress path ($p' \sim q$).....	15
Figure 2.9. Vacuum system (after Masse et al., 2001)	17
Figure 2.10. Arrangement method of drain board	19
Figure 2.11. Pore water pressure distributions under vacuum preloading	25
Figure 2.12. PVDs configuration.....	27
Figure 3.1. Scheme Tri-axial apparatus.....	34
Figure 3.2. The modeling of axisymmetric cell in FEM	35
Figure 3.3. Arrangement of instrumentations.....	36
Figure 3.4. Schematic illustration of Asaoka's method.....	37
Figure 4.1. The boundary condition of axisymmetric cell	42
Figure 4.2. Case n=10, vacuum only; $V_a=50$ kPa	44
Figure 4.3. Case n=20, Vacuum only; $V_a=50$ kPa	44
Figure 4.4. Case n=10, Vacuum only; $V_a=100$ kPa	45
Figure 4.5. Case n=20, Vacuum only; $V_a=100$ kPa	45
Figure 4.6. Ratio of Time factor $\sim U(\%)$ for Vacuum stage only	46
Figure 4.7. Vacuum combine surcharge preloading	47
Figure 4.8. Case n=20, Vacuum - Surcharge;.....	48
Figure 4.9. Case n=20, Vacuum - Surcharge;.....	48

Figure 4.10. Case n=20, Vacuum - Surcharge; $V_a=50\text{kPa}$, $U=100\%$	49
Figure 4.11. Ratio of Time factor $\sim U(\%)$ for Vacuum - Surcharge preloading	49
Figure 4.12. Case n=20, Vacuum - Surcharge;.....	50
Figure 4.13. Case n=20, Vacuum - Surcharge;.....	51
Figure 4.14. Case n=20, Vacuum - Surcharge;.....	51
Figure 4.15. Void ratio $\sim \log(p')$ graph.....	53
Figure 4.16. Predict shear strength by effective stress and earth ratio	53
Figure 4.17. Behavior of soil mass under vacuum and surcharge preloading	54
Figure 4.18. Excess pore water pressure in vacuum condition	55
Figure 4.19. Soil specimen under Vacuum condition	56
Figure 4.20. Case n=20, Vacuum only; $V_a=50\text{ kPa}$, $U=100\%$	58
Figure 4.21. Case n=20, Vacuum - Surcharge; $V_a=50\text{kPa}$, $U=100\%$	59
Figure 4.22. Case n=20, Vacuum - Surcharge; $V_a=50\text{kPa}$, $U=100\%$	59
Figure 4.23. Increasing un-drain shear strength	60
Figure 4.24. Stress path	60
Figure 4.25. Increasing undrained shear strength.....	61
Figure 4.26. The CVM is applied.....	63
Figure 4.27. The cross section of the Taxiway.....	63
Figure 4.28. Soil profile of the project	64
Figure 4.29. Log of boring.....	66
Figure 4.30. Arrangement of instrumentations.....	68
Figure 4.31. The schematic of CVM	69
Figure 4.32. The vacuum preloading stages	70
Figure 4.33. The final settlement-Zone GI-1 by Asaoka's method.....	71
Figure 4.34. The settlement at zone GI-1	72
Figure 4.35. Field monitoring Zone 1&2	72
Figure 4.36. Pore water pressure from piezometer data	73
Figure 4.37. Problem during surcharge applying in Zone 3,4.....	73

Figure 4.38. Dissipation of excess pore water pressure	74
Figure 4.39. Predict DOC by dissipation of the excess pore water pressure (EPWP)	75
Figure 4.40. The discharge of zone GI-1 & GI-2	75
Figure 4.41. The real excess pore water pressure.....	77