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Department of Structural Engineering

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Ain Shams University

“Analysis of Stone Columns in Soft Soils under Vertical Loading Considering the Construction Effects on the Enfolding Soils”

A Thesis

Submitted in Partial Fulfillment for the Requirements for the Degree
of Doctor of Philosophy in Civil Engineering – Structural Department

BY

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TABLE OF CONTENTS

<u>TITLE</u>	<u>Page</u>
ACKNOWLEDGEMENT.....	I
ABSTRACT.....	II
TABLE OF CONTENTS.....	IV
LIST OF TABLES.....	X
LIST OF FIGURES.....	XI
CHAPTER (1): INTRODUCTION	1
1.1 Problem Statement	1
1.2 Objectives	2
1.3 Research Plan	2
1.4 Thesis Organization	3
CHAPTER (2): LITERATURE REVIEW	
2.1 GENERAL	6
2.1.1 Construction Processes	7
2.1.1.1 Poker	7
2.1.1.2 Dry Top Feed System	8
2.1.1.3 Wet Top Feed System	9
2.1.1.4 Dry Bottom Feed System	9
2.1.2 Applications of Vibro-Improvement	10
2.1.2.1 Settlement Control	10
2.1.3.2 Slope Stability	12
2.1.3.3 Mitigation of Liquefaction	13
2.1.3 Limitations of Vibro Replacement	13
2.2 GENERAL SETTLEMENT BEHAVIOR	14
2.2.1 Behavior of a Single Stone Column	14
2.2.1.1 Hughes & Withers (1974)	14

2.2.1.2 Narasimha Rao et. al. (1992)	15
2.2.2 Behavior of Stone Column Groups	16
2.2.2.1 David Wood et. al. (2000)	16
2.2.2.2 W. S. Bae et. al. (2002)	18
2.2.2.3 James McKelvey et al. (2004)	19
2.2.2.4 Gandhi and Ambily (2007)	19
2.2.2.5 Wehr (2004)	21
2.3 DEFORMATIONAL BEHAVIOR OF STONE COLUMNS ...	22
2.3.1 Case Studies	22
2.3.2 Laboratory Studies	24
2.3.3 Numerical Studies	27
2.3.3.1 Balaam et al. (1977)	27
2.3.3.2 Domingues et al. (2007).....	29
2.3.3.3 Sondermann and Kirsch (2003)	30
2.3.3.4 Wehr and Herle (2006)	31
2.3.3.5 Elshazly et al. (2008a)	32
2.3.3.6 Kirsch (2008)	34
2.4 COLUMN INSTALLATION EFFECTS	35
2.4.1 Laboratory Investigations	36
2.4.2 Observed Field Measurements	37
2.4.3 Simulation of Installation Effects using Numerical Models	40
2.4.3.1 Mobilized Lateral Earth Pressure Coefficient	40
2.4.3.2 Cylindrical Cavity Expansion	41
2.4.3.3 2.4.3.3 CCE and Improved Stiffness of the Enfolding Soil.....	42
2.5 DESIGN METHODS	
2.5.1 Unit-Cell Concept	43

2.5.2 Ultimate Bearing Capacity	44
2.5.2.1 Thorburn & MacVicar (1968)	44
2.5.2.2 Hughes & Withers (1974)	45
2.5.3 Magnitude of Settlement	46
2.5.3.1 Greenwood (1970)	46
2.5.3.2 Aboshi et. al. (1979)	47
2.5.3.3 Priebe (1995)	47
2.5.3.4 Balaam & Booker (1981)	50
2.5.4 Rate of Settlement	52
2.5.4.1 Han & Ye (2001)	52
2.5.4.2 Castro & Sagaseta (2009)	54
2.6 SUMMARY OF THE LITERATURE REVIEW	56
CHAPTER (3): FE MODELING & VERIFICATIONS	
3.1 INTRODUCTION	59
3.2 CONSTITUTIVE MODELS	62
3.2.1 Mohr Coulomb Model (MCM)	64
3.2.2 Hardening Soil Model (HSM)	68
3.2.3 Soft Soil Model (SSM)	71
3.3 MODEL VERIFICATION	74
3.3.1 Bothkennar Soil Profile	74
3.3.2 Untreated-Foundation Loading-Test	79
3.3.3 Stone Column Group Loading Test	82
3.3.3.1 The Influence of Soil Models on the Bothkennar Soil Profile's Load-Settlement-Time Performance	84
3.3.3.2 Load–Settlement-Time Performance Validation of Treated Foundations using Stone Column Group	86

CHAPTER (4): MODELING OF STONE COLUMNS WITH CONSIDERING THE INSTALLATION EFFECTS

4.1 INTRODUCTION	91
4.2 HYPOTHESIS	91
4.3 OBJECTIVES	93
4.4 FEM OF A SINGLE STONE PILLAR	93
4.4.1 Model Geometry	93
4.4.2 Column-Soil Interaction	94
4.4.3 Installation Modeling	95
4.5 RESULTS AND DISCUSSIONS	98
4.5.1 Short-Term Performance	98
4.5.1.1 Horizontal (Lateral) Displacement (U_x) ...	99
4.5.1.2 Excess Pore Water Pressure, PWP, (P_{excess})	102
4.5.1.3 State of the Enfolding Soil after Installing a Single Stone Column	103
4.5.2 Long-Term Performance	105
4.5.2.1 Evaluation of Stress state after Installation...	105
4.5.2.2 Evaluation of Stiffness Variation after Installation	108
4.5.2.3 Evaluation of K/K_o and E_m/E_o with Depth after Installation	112
4.5.3 Foundation Loading Performance	113
4.5.3.1 Ultimate and Allowable Bearing Capacities ..	114
4.5.3.2 Settlement Performance	118
4.5.3.3 Stress Concentration Ratio	120
4.6 RECOMMENDEDATIONS	122
CHAPTER (5): FEM FOR A WIDE FOOTING TREATED BY A HUGE GROUP OF PILLARS "CASE STUDY (I)"	
5.1 INTRODUCTION	125

5.2 OBJECTIVES	125
5.3 HYPOTHESIS	125
5.4 SANTA BARBARA "CASE STUDY (I)"	127
5.4.1 Detailed Information	127
5.4.2 Objectives	134
5.4.3 Finite Element Modeling of Case Study (I)	135
5.4.3.1 Axisymmetric finite element analysis using PLAXIS 2D 2018	135
5.4.3.1.1 Installation of one column	137
5.4.3.1.2 Installation of an Adjacent Column ..	144
5.4.3.2 Three-dimensional modeling of vertically loaded columns	156
 CHAPTER (6): FEM FOR AN ISOLATED FOOTING REINFORCED BY A SMALL GROUP OF STONE COLUMNS "CASE STUDY (II)"	
6.1 INTRODUCTION	163
6.2 OBJECTIVES	163
6.3 TAMAN DESA "CASE STUDY (II)"	163
6.4 FE MODELLING OF CASE STUDY (II)	178
6.4.1 Introduction	178
6.4.2 2D Modeling of the Stone Columns Installation Process	181
6.4.3 3D Modeling of the Stone Columns Group	184
6.5 VALIDATION PROCESS	187
 CHAPTER (7): PARAMETRIC ANALYSES	
7.1 INTRODUCTION	190
7.2 OBJECTIVES	190
7.3 PARAMETRIC STUDY	191
7.3.1 Finite Element Analyses using Case Study (I)	191

7.3.2 Finite Element Analyses using Case Study (II)	198
7.3.2.1 Column stiffness ratio (E_{sc}/E_{ss})	199
7.3.2.2 Area replacement ratio ($a= A/A_c$)	201
7.3.2.3 Float ratio ($F = L_{sc}/H_{ss}$)	202
7.3.2.4 Column length ratio ($\lambda=L_{sc} /B_f$)	203
7.3.2.5 Levelling layer ratio ($f= h_{layer}/d_c$)	204
 CHAPTER (8): CONCLUSIONS AND RECOMMENDATIONS	
8.1 INTRODUCTION	205
8.2 INSTALLATION INFLUENCE OF PILLARS	207
8.2.1 Improvement Zone around a Single Stone Column	208
8.2.2 Improvement in Stiffness and Stress State Parameters	209
8.2.3 Load-Settlement Performance considering the Installation of a Single Stone column	210
8.3 VERIFICATION OF FEM USING THE WELL- DOCUMENTED SANTA BARBARA CASE STUDY	212
8.3.1 Installation of a Single Stone Column	213
8.3.2 Installation of an Adjacent Column	213
8.3.3 3D Modeling of the Loading Stages	215
8.4 EFFECT OF CONSTRUCTION TECHNIQUE ON THE IMPROVEMENT OF THE INITIAL SOFT SOIL	216
8.5 APPLICATION OF THE COMBINED FE FRAMEWORK ON TAMAN DESA CASE STUDY (II).....	217
8.6 DESIGN FRAMEWORK FOR STONE COLUMNS WITH CONSIDERING INSTALLATION EFFECTS	219
8.7 CONCLUSIONS	221
8.8 RECOMMENDATIONS FOR FUTURE STUDIES	224
REFERENCES.....	XV

LIST OF TABLES

<u>TITLE</u>	<u>Page</u>
CHAPTER (3): FINITE ELEMENT MODELING & VERIFICATION	
Table (3.1): Summary of the parameters of geotechnical materials used in the Bothkennar test site analysis	78
Table (3.2): Summary of the stone column treated foundation test configurations for Bothkennar soil profile	83
Table (3.3): Summary of loading increments over Bothkennar soil profile for stone - column tests	84
Table (3.4): Measured and predicted settlement in Bothkennar soil profile at different stress levels and footing durations (8)	86
CHAPTER (5): FEM FOR A WIDE FOOTING REINFORCED BY A LARGE GROUP OF STONE COLUMNS "CASE STUDY (I)"	
Table (5.1): Strata definitions of Santa Barbara's soil profile	131
Table (5.2): Footing and fill parameters for Santa Barbara case study	134
CHAPTER (6): FEM FOR AN ISOLATED FOOTING REINFORCED BY A SMALL GROUP OF STONE COLUMNS "CASE STUDY (II)"	
Table (6.1): Footing and stone column parameters for Taman Desa test	179
Table (6.2): Soil parameters of Santa Barbara's soil profile	181

FEM FOR AN ISOLATED FOOTING REINFORCED BY A SMALL GROUP OF STONE COLUMNS "CASE STUDY (II)"

6.1 INTRODUCTION

The FE simulation of the case study presented in Chapter 5 proved the significant enhancement of the enfolding soft soils of a group of stone columns due to the installation process. The load-settlement performance indicated by the combined FE analyses has been validated using a well-documented case study. Three stone column configurations with three load-settlement performances were employed; however, all configurations represent a vertically loaded single stone column. Thus, application of the combined finite element analyses to a vertically loaded stone column group is needed. PLAXIS 2D is employed to simulate the installation process, and PLAXIS 3D is employed to simulate the loading process considering the outputs from the 2D analysis.

6.2 OBJECTIVES

The main goal of this chapter is to simulate a well-documented case study of a vertically loaded stone columns group, supporting an isolated footing, using combined 2D and 3D analyses, as presented in Chapter 5. A direct comparison between the load-settlement performance revealed by the FE analyses and the load-settlement performance indicated by the field investigations has been conducted to demonstrate the efficiency of the combined simulation procedures in capturing the real load-settlement behavior of the stone columns group.

6.3 TAMAN DESA "CASE STUDY (II)"

In summer 2002, instrumented load tests were conducted to determine the group bearing behaviors of stone columns. The region

around Kuala Lumpur in Malaysia was chosen as the location of the loading tests. The soft soils in this region were extensively employed for the ground improvement using stone columns. This economically emerging region in Southeast Asia has a considerable demand on efficient infrastructures, which is the main reason that stone columns are employed instead of deep foundations. Thus, extensive well-documented load tests for stone columns groups are critical.

The case study discussed in this section involves a group of five vibro stone columns that are tested in Taman Desa, which is a suburb of Kuala Lumpur. The creation of a motorway interchange of the New Highway Pantai, includes the construction of embankments. Improvement of the encountered soft soils using stone columns was required. For research purposes, a part of the site has been assigned for long-term load tests to examine the real field performance of the treated soil. A bottom-feed method has been utilized for the entire site, with the exception of the testing area. To ensure comparability with the situation in Europe, the stone columns in the load tests have been constructed using a dry bottom-feed method.

The ground in the region around Kuala Lumpur is characterized by soft fluvial sedimentary soils in the central mountains of the Malaysian peninsula. These sedimentary deposits are geologically young—usually younger than 10,000 years—with layer thicknesses of 30 m. Poulos (2002) shows a map of the Southeast Asian region that indicates regions with buildings characterized by these sediments, as shown in Figure (6-1). As part of the sample field, extensive soil investigations were performed. Generally, thirteen holes have been drilled in the construction site of the Taman Desa Interchange; they are continuously sampled using the standard penetration test. In addition, 23 cone penetration tests were conducted on the ground of the loading test area. Figure (6-2) shows a

plan view of the construction site that depicts the positions of digestions and site equipment and the location of the field samples.

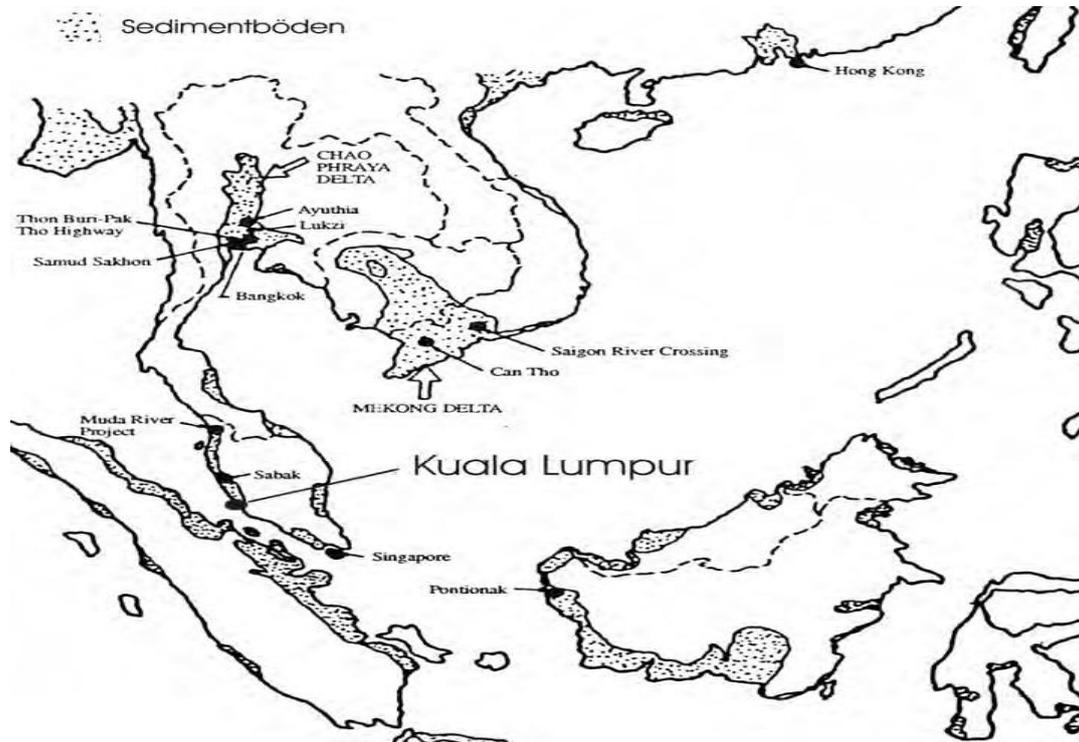


Figure (6.1) Fluvial sedimentary soils in Southeast Asia

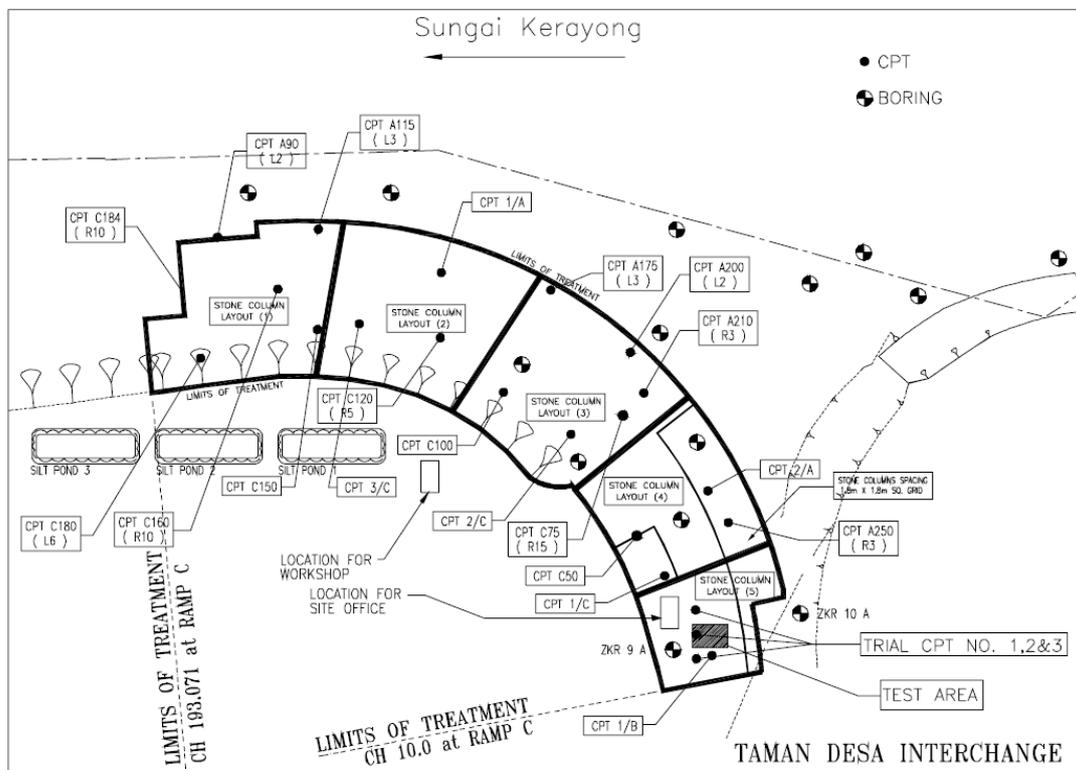


Figure (6.2) Plan of the construction site at Taman Desa Interchange

The first several meters below the ground surface are composed of sandy fillings, followed by a soft clay layer to a depth of 12 m at the location of the sample loading, and then a base layer of sandy silt. Figure (6-3) presents the results of two boreholes in the direct vicinity of the load-test field and the associated SPT numbers.

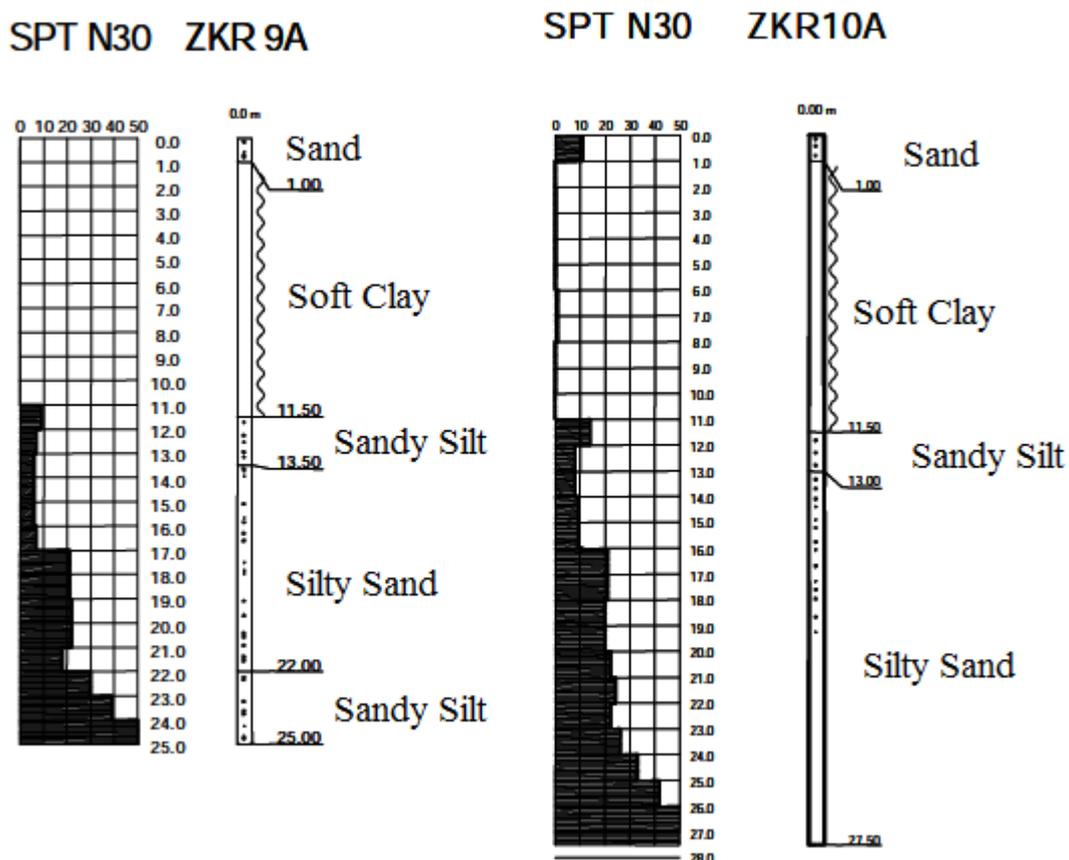


Figure (6.3) Boreholes ZKR9A and ZKR10A with SPT results

In the soft clay, no standard penetration test can be performed. Therefore, the results of the cone penetration tests are used to estimate the soil mechanical properties. Figure (6-4) shows two CPT profiles at the site of the loading test. The Robertson chart can be employed in the classification of soft clay. Figure (6-5) presents the corresponding diagram of the Robertson and Powell (1997) classification system, which presents the value range for the penetration tests at the Taman Desa Interchange. Accordingly, the soil can be regarded as normally

consolidated silty clay. For further classification of the clayey soil, undisturbed samples have been collected and examined in the laboratory. All parameters of the silty clay at the testing site have been determined and employed in the finite element analysis.

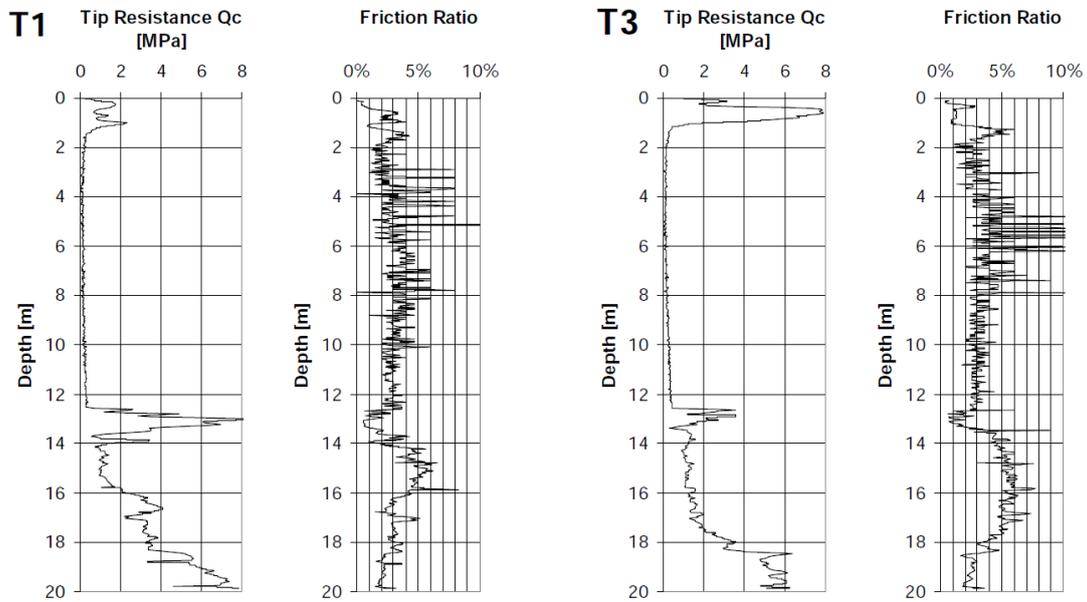


Figure (6.4) Result of the cone penetration test T1 and T3 at Taman Desa

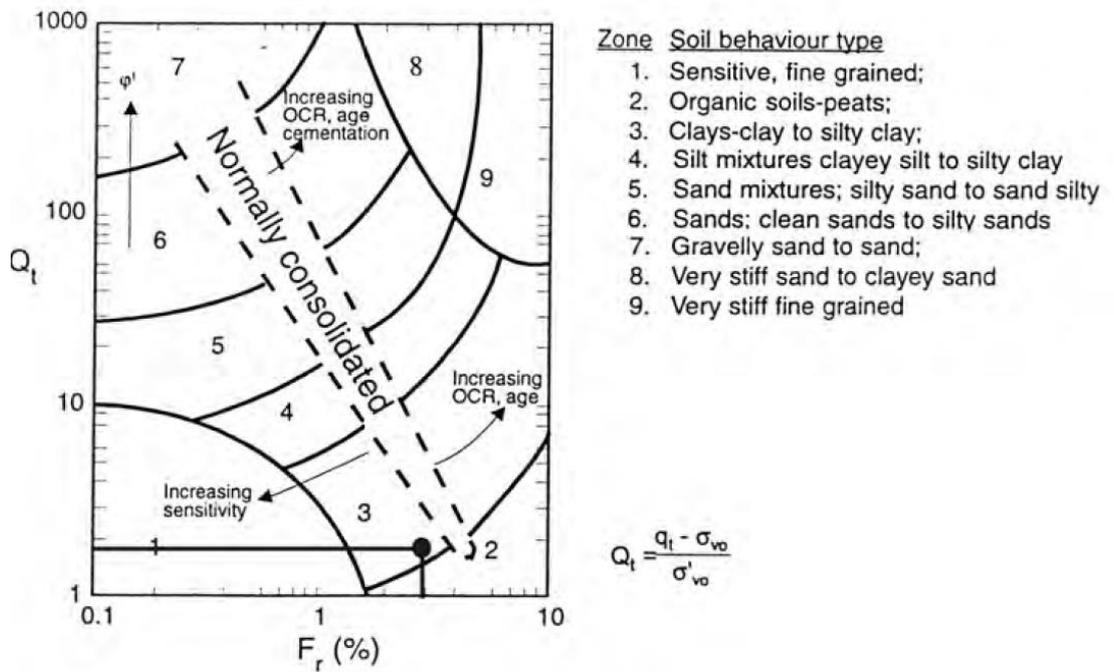


Figure (6.5) Clay classification system; Robertson and Powell (1997)

The determination of the shear parameters was performed in triaxial tests. In addition, hand vane tests were performed at a depth of 2.2 m. The undrained results indicated a triaxial unconsolidated undrained shear strength of $c_{u, \text{Triax UU}} = 20.0$ kPa, which was consistent with the results of the hand vane tests. An additional three CU triaxial tests and nine CD triaxial tests with speeds of 0,001 mm/min have been performed, and the detection of the volume change were performed to determine the drained shear strength. Figure (6-6) summarizes the results. The rigidity coefficients were determined by *in situ* measurements and odometer tests on undisturbed samples in the laboratory.

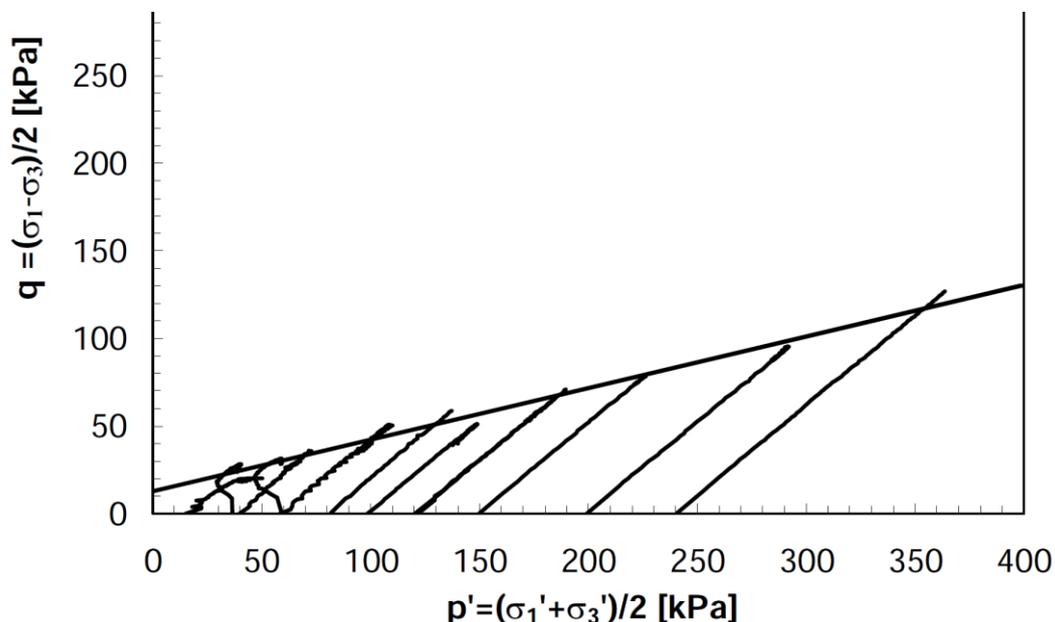


Figure (6.6) p' - q diagram of the triaxial tests

Prior to the installation of stone columns, pressuremeters (PM1 and PM2), earth pressure sensors (EPP: E, EBi: S1/1 and EBi: S1/2) and a pore-water-pressure transducer (EPP: PWD) were installed in the ground. First, a cavity was produced by the pressing in and retrieval of a cylindrical replacement body. Thereafter, the pressuremeters or the earth and pore water pressure transducer were pressed from the bottom of the cavity. These tools were arranged in a manner that enabled them to