CHAPTER 1

INTRODUCTION

1.1 Changing Landscapes of Singapore

The Republic of Singapore, consisting of one larger and several smaller islands lying at the southern end of the Malay Peninsula, is a roughly diamond shaped area (Figure 1-1) between latitude $1^{o}09'$N and $1^{o}09'$N and longitude $103\ ^{o}38'$E and $104\ ^{o}06'$E. It is surrounded from north-east to north-west by West Malaysia being separated from it by the Selat Johor, a stretch of water varying from 0.7km to 2.5km in width. To the south, at a distance of some 12km to 15km from the island of Singapore is the Riau Archipelago of Indonesia (Public Works Department, 1976).

The history of modern Singapore began in 1819 and before that the physical landscape was relatively untouched by human activity (Savage, 1992). However, the latter half of the 20^{th} century saw the rapid and dramatic process of urbanization, which involved mass construction works and highly planned modification to the landscape. During the past decade, many major projects such as high-rise buildings, expressways, Deep Tunnel Sewage System (DTSS) and Mass Rapid Transit (MRT) north-east line have been undertaken and many projects such as MRT circle line are still going on.

1.2 Necessity for Soil Characterization

Needless to say, the extensive building, excavation and tunneling works have led to the requirement of a more accurate description of soil properties. However, the majority of the available soil data in Singapore are from site investigation reports that were prepared for foundation or other substructure designs and only basic engineering parameters were determined. The quality of the data is generally difficult to assess and questions concerning the degree of sampling disturbance are seldom discussed (Tan *et al*., 2003).

Realizing these problems, the National University of Singapore has initiated a big research program, trying to characterize the natural soils of Singapore. This thesis forms part of it, working on one type of soils, the Singapore Old Alluvium (OA).

1.3 Singapore Old Alluvium (OA)

On Singapore Island, Old Alluvium (OA) is mainly found in eastern part of the main island and a small patch of OA can also be found in the northwest part, as shown in Figure 1-1. The constituents of OA are by-products of weathering of mountain slopes of granite and low-grade metamorphic rocks in southern Malaysia. The weathered material was then quickly transported by an ancient braided river system and deposited rapidly. The soil is a mixture of sand, gravel, silt and clay. Generally speaking, it is a dense material with its colour varying from white, gray, yellow, and brown to red, or a mixture of these colours.

The OA is assumed to be a stiff and uniform formation, but actually it is far from a uniform soil and its properties vary both horizontally and vertically. The existing

knowledge of OA engineering properties is limited, and inconclusive because of the great degree of scattering in the results collected.

1.4 Objectives of Research Work

From the available data, OA is heterogeneous and the shear strength data are highly scattered, and show no apparent relationship with either depth or void ratio, as shown in Figure 1-2. This thesis aims to provide a characterization framework, which will offer a better insight into the reasons for this heterogeneity.

Presently, not enough attention is paid to this natural heterogeneity of the OA, which can have important implications for designing and construction. Currently characterization is often based on shear strength or SPT N values. However, OA is deposited by a braided river system in tropical environment, and great heterogeneity exists both horizontally and vertically. To achieve a better understanding of OA, the natural heterogeneity has to be dealt in soil characterization.

To develop a framework to characterize Singapore OA, extensive laboratory testing needs to be carried out on “undisturbed” intact natural soil samples. During the sampling process, inevitably some changes in stress and strain state occur. Without an idea of the impact of this sampling disturbance, it is difficult to assess how well the test data reflect the real properties of OA. Thus, investigation on sampling disturbance of OA is a prerequisite for this soil characterization project.

Little is known about the in-situ stress state of OA. The vertical stress is relatively easy to determine but the in-situ horizontal stress is a very difficult topic to tackle. Since

the goal of soil characterization is to offer guidance to real world engineering problems, the in-situ stress state must be studied.

The objectives of this research program can be summarized as following:

1) To develop a characterization framework to deal with the heterogeneity of OA
2) To examine the effect of sampling on OA.
3) To investigate the in-situ horizontal stress of OA.
4) To understand the governing factor of OA shear strength.

Both laboratory and in-situ testing were involved in this research project. High quality OA samples were taken from Kim Chuan site and Tanah Merah and the locations are shown in Figure 1-1.

1.5 Organization of Thesis

This thesis presents the research work conducted on the Old Alluvium. Chapter 2 presents a literature review on Old Alluvium and other related topics such as shear strength of sand and sand mixture, coefficient of earth pressure at rest K_o and in-situ horizontal stress, and sampling effects. The geological aspects of Old Alluvium, including source of material, depositional environment, post-depositional processes and stress history are also discussed based mainly on works by other researchers. The agreements and disagreements among these researchers are highlighted.

Chapter 3 introduces the experimental apparatus and laboratory handling of soil samples in this project. A set of classification tests are developed to classify OA. Test equipment includes the triaxial system, the GDS stress path cell system, the oedometer

cell specially made to measure horizontal stress and others. Calibration information is also presented.

Chapter 4 investigates the sampling effects. Laboratory tests simulating ‘perfect sampling’ and ‘ideal tube sampling’ are carried out using reconstituted samples. Intact samples are also taken from Kim Chuan site using Mazier, Thick-wall and Block sampling. The triaxial results of these samples are compared and disturbance caused by sampling are revealed.

Chapter 5 deals with K_o values and in-situ horizontal stress of OA. Triaxial and oedometer K_o consolidation tests are performed using sand samples with different clay contents. Field pressuremeter tests are performed at Kim Chuan site and the results are analyzed using graphical iteration methods.

Chapter 6 is focused on the shear strength of OA and the stiffness of OA is also addressed. Based on the literature review of sand and sand mixture, it is found important to recognize the contribution of different fines to the shear strength. The roles of plastic and non-plastic fines are first examined. A recently introduced concept of equivalent granular void ratio, e_{ge}, is explored. It is found to be very useful for the characterization of sand mixture of a wide particle range such as Singapore OA.

Finally, Chapter 7 presents the conclusions drawn in this research project and recommendations for further research on Singapore Old Alluvium.

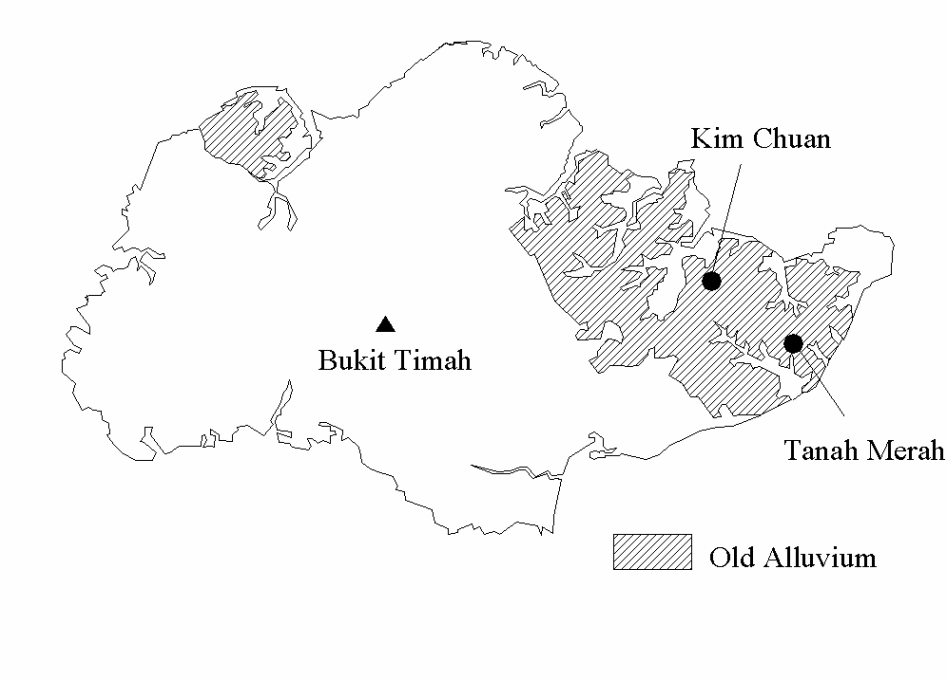

Figure 1-1 Map of main island of Singapore and Old Alluvium surface distribution

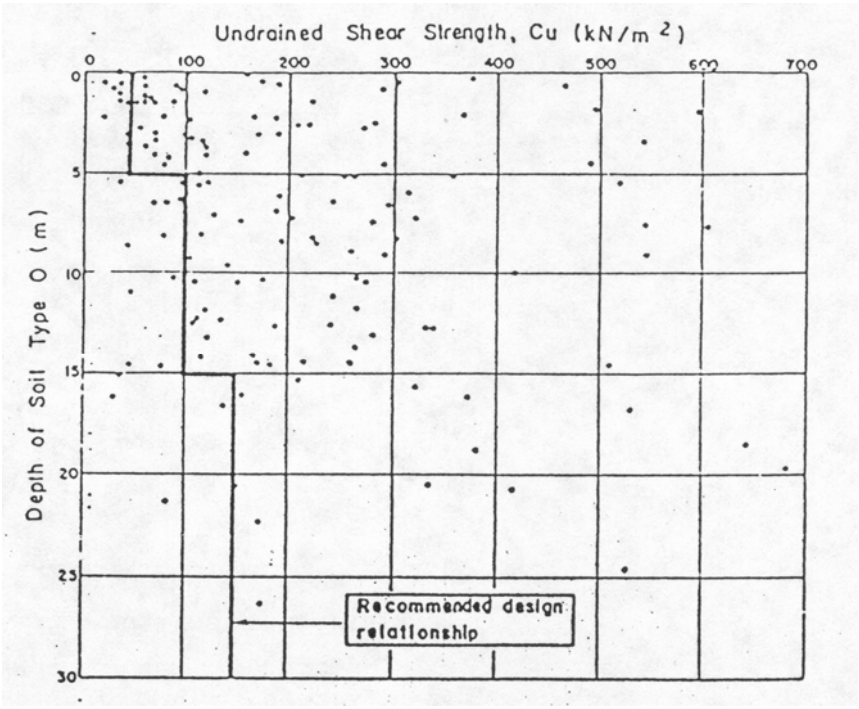

Figure 1-2 Data of early study on OA shear strength and depth (after Dames & Moore, 1983)