1.0 INTRODUCTION

1.1 Statement of the Problem

Geologic changes in soil composition, texture, and properties may require hundreds to thousands of years. Over time, soils can turn into rocks, and rocks weather to form soils. In the last thirty five years, however, it has been realized that there are also changes in the properties of soils that can occur in weeks, months, and years, times more relevant to engineers. Such changes are called aging effects. Leonards and Ramiah (1959) first found that for a normally consolidated clay, periods of secondary compression caused an increase in stiffness and preconsolidation pressure. Much subsequent work on the aging of soils has focused on cohesive soils, where time dependent increases in modulus, dilatancy, and preconsolidation pressure can be easily measured.

Within the last fifteen years, there has been increasing evidence that short-term property increases can also develop in sand deposits with little or no fines. These aging effects refer to increases in strength and stiffness, which develop under constant effective stress after deposition, disturbance, and/or compaction. Much of this evidence comes from in situ tests like the cone and standard penetration tests. Time dependent increases in penetration resistance have been measured in hydraulically placed fills and freshly densified deposits, with some of the largest increases following the use of ground modification techniques such as vibrocompaction, dynamic compaction, and blast densification.

The following example illustrates the impact that aging effects can have on the measured cone penetration resistance of sands following ground modification. For the construction of a large embankment dam and seepage blanket across the Jebba River in Nigeria, it was determined that the underlying soil deposits required densification in order to prevent excessive differential settlements and to reduce the potential for liquefaction during a large earthquake (Mitchell and Solymar 1984). The soils in question were deep deposits (up to 70 m) of clean sand and, due to the depth of some of the loose zones, vibrocompaction was used to densify the upper 25 meters, and blast densification was used to improve the soil at depths between 25 and 40 meters.

For both ground modification methods, there was a significant time dependent increase in the cone penetration resistance, as shown in Figures 1.1 and 1.2 for vibrocompaction and blast densification, respectively. These changes occurred despite no measured changes in density of the sand and rapid dissipation of excess pore pressures. In fact, there is a general lack of understanding as to what causes the time dependent increases, and currently there is no generally accepted way to account for aging effects in engineering practice.

There are clear, practical advantages to understanding more about these time dependent phenomena in sands. If the factors which influence the presence and magnitude of aging effects were known, these effects could be incorporated into practice to make ground modification techniques a more economical alternative for improving sandy soils. Such an understanding would be of relevance to geotechnical engineers in general and of great interest to the ground modification community.

Since the publication of the Jebba Dam case history in 1984, there have been an increasing number of examples of aging effects in sands published in the literature. Although most of the examples have involved ground modification techniques as mentioned above, other examples from laboratory studies on sands include changes in the small strain shear modulus, electrical and thermal conductivity, and liquefaction resistance. One interesting aspect of these examples is that, despite the increasing number of case studies where aging effects were measured, there are some examples where no aging effects were observed. Thus it does not appear that these effects occur in all cases, and it is not known what governs the development of these time dependent property increases.

Currently, there is a debate in the literature as to what are the underlying causes of this phenomenon. Generally, researchers fall into two categories: those who believe that aging effects are caused by a mechanical mechanism, and those who believe that a chemical mechanism is responsible. Although researchers on both sides have presented evidence and a limited number of test results to support their specific hypotheses, there is currently no unambiguous evidence identifying the underlying causes of the aging effects in sands. It is, therefore, the objective of this study to gain an understanding of the possible mechanisms responsible for aging effects in sands. To study the mechanisms, a detailed laboratory study was performed to isolate the significant variables that influence aging effects in sands. This is needed because a problem with the case studies published in the literature is that there is almost no control or mention of variables such as sand mineralogy, temperature, and pore fluid composition. As such it is very difficult to determine why there are large increases in penetration resistance in some cases and little or no increases in others. It is hoped that an understanding of the mechanisms responsible for aging effects in sands will lead to better-focused field studies and the eventual incorporation of these effects into geotechnical practice.

1.2 Scope of Research

The objective of this research is to gain an understanding of the possible mechanisms responsible for aging effects in sands. This was accomplished by a review of existing data from the literature and the development of a laboratory testing program to produce aging effects. The laboratory testing program was designed so that the influence of variables such as sand type, relative density, temperature, and pore fluid composition on aging effects could be studied. The specific properties that were observed with time are the small strain shear modulus, electrical conductivity and mini-cone penetration resistance.

This dissertation is divided into seven chapters. This chapter provides an introduction to the phenomenon of aging effects in sands and objectives of this research. Chapter two is a literature review of published examples of observed time-dependent property increases, and includes insight gained from the case studies. Chapter three is a discussion of the various mechanisms that have been presented in the literature, and chapter four describes the laboratory testing program developed to produce aging effects for this study. Background information for each test used is presented, as well as detailed descriptions of the apparatus and testing procedure used. The results of the testing program are presented and discussed in chapter five. In chapter six, a critical evaluation of all the data from this and other studies is presented to form a consistent picture of the phenomenon. Finally, conclusions of this research are presented in chapter seven, along with applications of this work for engineering practice and recommendations for future research.

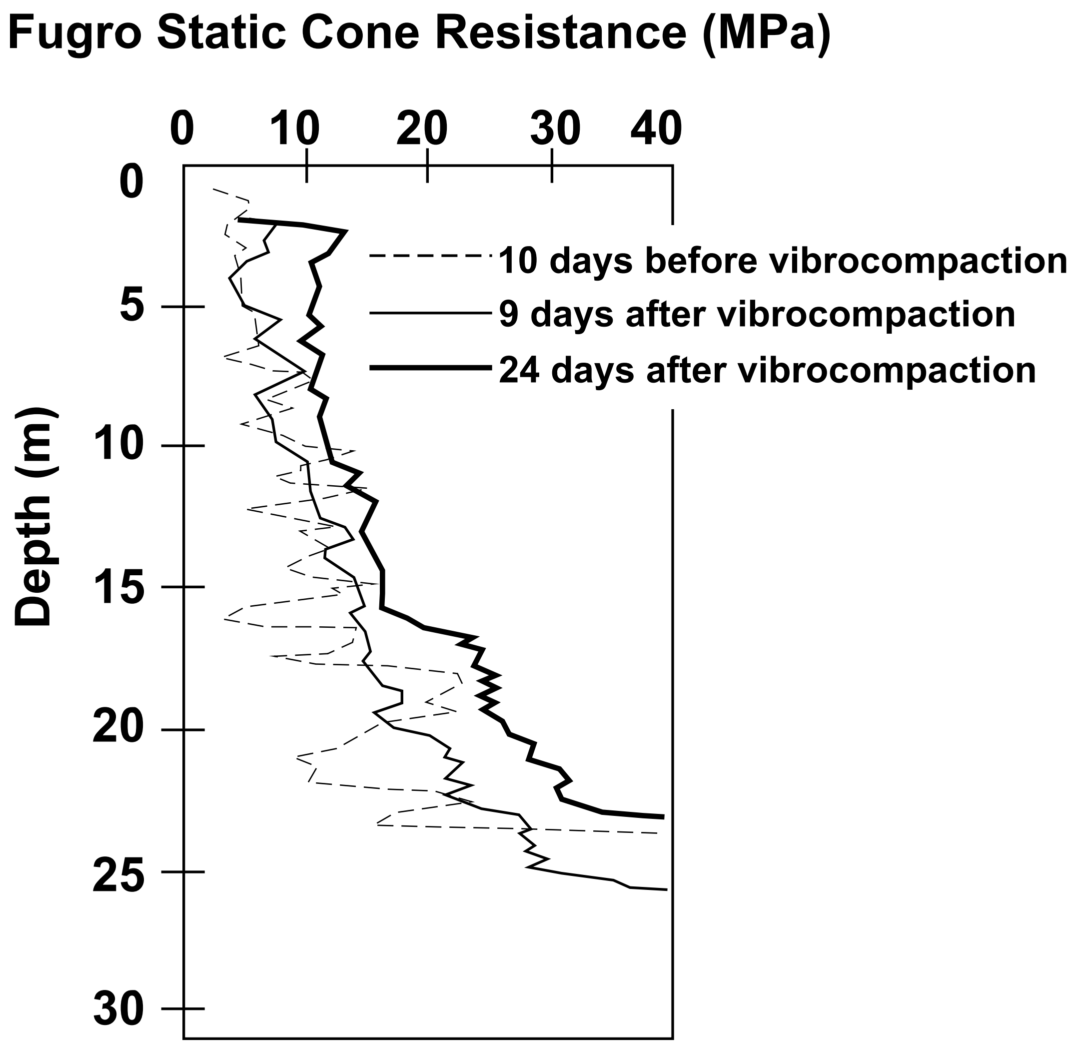

Figure 1.1 Example of aging effects following vibrocompaction (after Mitchell and Solymar 1984).

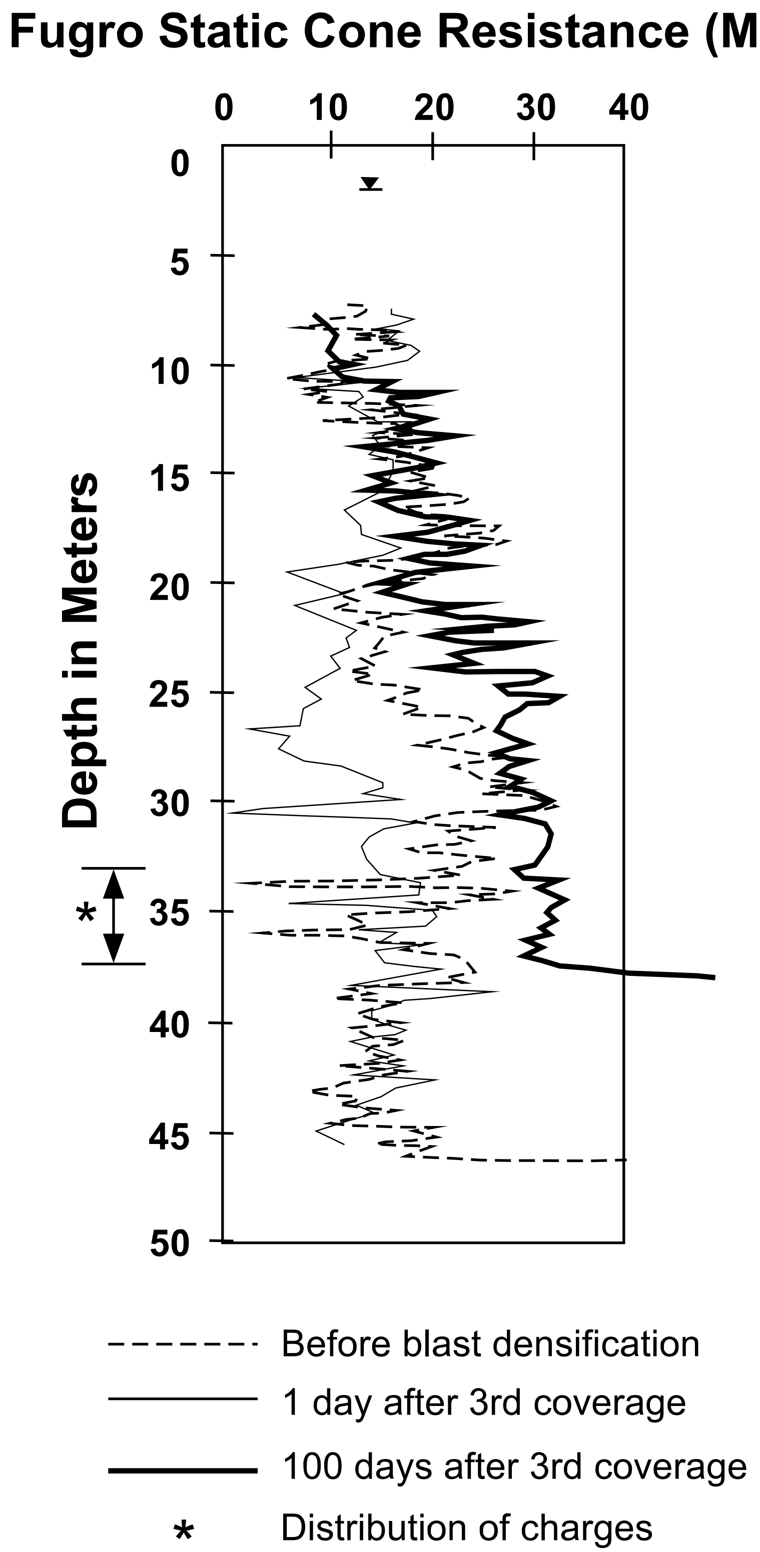

Figure 1.2 Example of aging effects following blast densification (after Solymar 1984).