CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A catastrophic failure of the Merriespruit gold tailings dam in February 1994, resulted in 17 fatalities, more than 200 injured, 80 houses destroyed, a further 200 houses severely damaged and more than R75mil in damage as 600,000 m^3 of liquefied slurry engulfed the township on the evening of the 22nd. Apart from graphically illustrating the risk of a tailings dam failure, the disaster sparked a campaign of renewed investigation into the safety of impoundment structures in South Africa. Tailings have been the subject of research in many countries around the world, especially those where mineral resources form a major part of the economy - South Africa being a good example. Nevertheless, very little research has concentrated on the fundamental composition of tailings and the influence thereof on the mechanical behaviour of this man-made material. Consequently a research programme has been initiated at the University of Pretoria to study the properties and behaviour of tailings.

This thesis constitutes the first step in defining the composition and state of typical South African gold tailings. Notable features include the use of the electron microscope and x-ray technology to examine the composition of tailings; exposure of a 5 m undisturbed tailings profile near the penstock of an impoundment; use of high quality undisturbed samples; as well as extensive laboratory tests to improve the interpretation of in-situ cone penetration data.

1.2 OBJECTIVE

The objective of this study was to investigate the composition and state of gold mine tailings to advance the state-of-the-art in understanding the mechanical behaviour of this material. The characterisation of tailings in their undisturbed state has always been complicated by difficulties in extracting undisturbed samples for controlled laboratory tests. For this study, both bulk and undisturbed samples of gold tailings have been subjected to methodical in-situ and laboratory testing to determine the in-situ composition and state. The material selected is representative of typical Witwatersrand gold tailings.

The behaviour of a tailings impoundment, as a geotechnical structure, is controlled by the state and composition of the in-situ material. For the purposes of this report these terms are defined below:

a) **Mechanical behaviour**: Stress-strain behaviour of a material described in terms of parameters that describe the fundamental and structural properties of the material, for example the effective angle of internal friction, ϕ', shear stiffness, G', and Poisson's ratio, ν. These parameters are used in design calculations or theoretical models to predict the load response for safety and serviceability assessments.

b) **Composition**: The composition of a soil is determined by the physical constituents and their properties together with the properties of the pore fluid. Physical properties that are of interest include: mineralogy, specific gravity, size distribution, shape and surface texture, whereas pH, colloidal solids and soluble solids are of importance in the pore fluid.

c) **State**: The state of a soil is governed by the state of the skeletal structure, i.e. the state of the packing arrangement including density and fabric as well as the nature of the inter-particle interactions or bonds. The state is partly a function of the history of loading and the current stress levels. Stress is usually defined in terms of effective stress resulting from the combined effect of the total stress and pore pressure regimes.

A tailings impoundment exists as a highly layered deposit of finely ground, silt sized, particles with mechanical properties intermediate between those of sands and clays. Generally, a raised impoundment is constructed with the coarser tailings sands serving as an embankment wall, and the finer slimes as internal fill. However, at any given location on an impoundment, individual layers can vary significantly in composition. Composition together with state will define the geotechnical behaviour under load. Factors that may be of importance in this regard include changes in composition between finer and coarser grades of tailings, as well as variances in state as a function of composition and structure. Of particular interest is the role of inter-particle forces including body-force components, surface charge effects and inter-particle bonding.

This study aims at defining the composition and state of gold tailings to serve as a basic model for understanding its geotechnical properties and behaviour, as follows:

a) Characterisation of the fundamental properties of the tailings solid particles including mineralogy, specific gravity, size distribution, particle shape and surface texture.

b) Determination of the compressibility and stiffness characteristics of fine and coarse tailings grades.

c) Investigation of the strength characteristics as a function of state and composition including in-situ structure.

d) Comparison of test results on reconstituted laboratory samples with tests on high quality undisturbed samples as well as in-situ piezocone tests.

1.3 SCOPE

Due to the extended nature of the study certain limitations have been imposed to permit a manageable project. These can be summarised as follows:

a) Subject material has been restricted to a gold tailings product from Vaal River Operations in the far west of the Witwatersrand.

b) Two impoundment sites were identified as relevant to the study. The first, Pay Dam - one of the older dams, was being recycled to extract remaining valuable content. The northern penstock on this dam had been washed open to a depth of 5 m by hydro-cannon. The site was used extensively for undisturbed sampling of fine and coarse deposits next to the penstock. It was also used to compare directly visual profiles with those deduced from in-situ piezocone tests. The second site, Mizpah - the latest addition on the mine, was representative of a well designed working impoundment. Bulk samples of fine and coarse deposits were collected from the beach-pond interface and a series of piezocone tests made from the daywall, across the beach and into the pond.

c) Samples were collected mainly from the pond areas of the impoundments where access is normally very difficult. In addition, a representative sample of the tailings delivery pulp was also taken.

d) Only saturated conditions were considered in this study, although samples were taken and piezocone probes made in the area above the water table, where de-saturation may have occurred. All laboratory tests concerned with compression and shear strength were performed on saturated samples, either as reconstituted slurries or by saturation of undisturbed specimens in the triaxial apparatus.

e) The study concentrated on the physical properties of the tailings particles and their effect on mechanical behaviour, although it is recognised that the pore fluid chemistry must play an important role. Wherever possible, the original pore fluid was retained in the undisturbed samples and for preparing specimens for indicator tests. In other cases, distilled water was added for grading and other purposes.

1.4 METHODOLOGY

To realise the objectives of this study samples of tailings were subjected to a comprehensive series of controlled laboratory tests. Results from these tests have been

compiled to describe the state and composition of the tailings and correlated with in-situ piezocone tests. Laboratory tests were performed using both reconstituted remoulded slurries and undisturbed samples. Test methods employed can be summarised as:

a) Basic indicator tests including particle size grading, specific gravity and Atterberg limits.

b) Use of electron microscope imagery for indications of particle size, shape and surface texture as well as undisturbed fabric.

c) X-ray emission spectrometry in the scanning electron microscope for elemental composition.

d) X-ray powder diffraction for mineral identification.

e) Compression and consolidation in the triaxial apparatus to examine stiffness and density states as a function of stress level and composition.

f) Undrained triaxial shear to examine strength dependency of the material on composition and state.

1.5 ORGANISATION OF THE THESIS

The thesis consists of the following chapters:

- *Chapter 1* serves as an introduction to the report.
- *Chapter 2* presents a review of the state-of-the-art on gold tailings and tailings structures from a survey of published literature.
- *Chapter 3* summarises all experimental work including site selection, sampling, laboratory as well as in-situ tests.
- *Chapter 4* discusses the results of the experimental program in terms of defining the in-situ composition and state of typical South African gold tailings.
- *Chapter 5* closes the thesis with a summary of the main conclusions.