CHAPTER ONE

INTRODUCTION AND MOTIVATION

1.1 Objectives of the study

The engineering characteristics of rocks and particularly, the shear strength of joints (discontinuities) in rock masses play a key role in civil engineering and specifically in the design and safety evaluation of dams. Civil engineers are confronted with the problem of shear strength when designing excavations in rock masses for structures such as dam foundations, cuttings in rock for roads (slopes), tunnels etc.

To evaluate the stability of a dam foundation, the shear strength of those joints with the most unfavourable orientations relative to the applied loads is required. Determination of the orientation of joints in a foundation by means of a joint survey is relatively easy. From this, the most unfavourably oriented joints can be selected. The design parameters for shear strength of these joints are usually not available during the early stages of the design and it is thus necessary to estimate these. It is therefore the aim of this investigation to provide a guideline for the estimation of these shear strength characteristics as accurately as possible.

The objective of this research project was to determine and to analyse the shear strength of joints in a number of rock types, sampled at different locations and to classify these strengths in accordance with joint surface parameters. The information so obtained serves as a data bank of shear strength parameters for the design of new dams and for the evaluation of the safety of existing dams in South Africa.

The shear strength of joints in rock is also of importance for the design of slopes in rock for roads and railways and for mining excavations as well as for the design of tunnels for civil and mining engineering applications. The information presented in this report will therefore also be of use to engineers in the design of such structures.

1.2 Motivation

A large proportion of South Africa's economically most active population lives in the Gauteng Province, which is situated on a watershed. Furthermore, South Africa is a relatively dry country that necessitates that water storage dams have to be built in suitable riverbeds from where the water has to be transferred to the end users by means of pump stations, pipelines, tunnels and canals. A number of major water schemes have been constructed, e.g. the Drakensberg Pumped Storage Scheme, the Orange-Fish River Scheme and the Lesotho Highlands Water Project currently under construction. Increasing the capacity of existing schemes will become necessary and further, similar schemes will have to be constructed in the future to satisfy the ever-increasing demand for water in the RSA. A number of dams in our country have reached ages of 40 years and more with the result that their safety and stability will have to be re-evaluated.

The stability of a dam depends on its design, on the materials and methods used during its construction and on the stability of the foundations on which it is built. The characteristics of the rocks and particularly the shear resistance of the joints in the rocks are very important design parameters. The latter parameter has generally not received the necessary attention, mainly because it cannot be determined quickly and cheaply. An additional explanation is that obtaining representative rock samples is very difficult and often only the more competent materials survive the sampling processes.

A large number of rock types occur in southern Africa. These include igneous, sedimentary and metamorphic rocks. A database including the widest range is thus preferable. The types of rocks tested include in this investigation were: sandstone of the Cape Supergroup; post-Karoo dolerite; mudstone, sandstone, of the Karoo Supergroup; and granite of the Basement Complex.

1.3 The history of the study conducted

The duration of the study was ten years, from 1992 until 2002. This study formed part of a more extensive study to determine the engineering characteristics of important southern African rock types with the emphasis on the shear strength of concrete dam foundations (Geertsema, 2000). The Water Research Commission (WRC) was the main funder of this project.

The study has been executed in five distinct phases. The first phase, took place between 1992 and 1993 and consisted of a literature survey with the aim of collecting and studying data on the engineering properties of different types of rock from southern Africa and elsewhere, as well as of worldwide origin. The literature study was updated during 2002-2003. During this phase the United Kingdom, Norway and the United States were visited by the author, to study inter alia their methods of determination of the engineering characteristics of rocks and particularly also their equipment for shear testing. During the same period, the Department of Water Affairs and Forestry (DWAF) designed a large shear box. The shear box was built during 1993 – 1995. This shear box was used for testing of large samples during this research project.

During the second phase a sampling programme was undertaken and the general engineering properties of the sampled southern African types of rocks were determined. During 1995 a scanning apparatus was developed and built. This apparatus scans the surface of a rock specimen and can produce a contour map of the scanned surface, which can be used to describe quantitatively the surface topography and thus the roughness of the rock joints to be tested.

The third phase, from 1994 to 1999, consisted of an intensive testing programme during which NX-size (54,5 mm diameter) cores were used to determine the shear strength (basic and residual) of the selected rock materials. In addition, the large specimens collected for testing in the large shear box at the DWAF were characterised and a number of these were tested.

During the fourth phase a number of shear tests on large specimens were conducted at the DWAF – (both 'wet' and 'dry').

The last phase conducted between 1999 and 2000 included a sampling and testing programme of three specimen of granite. The purpose of this phase was to apply the knowledge and experience gained during the previous part of the project, to calibrate the results obtained previously. This thesis was written during 2001 and 2002. Additions were made during 2003.

The investigation experienced a number of serious delays for which the main reasons were:
(a) The large shear box developed by the DWAF was delivered late and in addition, problems were experienced with its computerised control system.
(b) The resignation of the technician who had been appointed in a full-time capacity to work on the project.
(c) The illness of the researcher during 1996.

As a result of the test machine being new, and that a learning curve had to be followed by the investigators to familiarise themselves with the equipment, more time was spent on this phase that was anticipated. The taking of large rock samples was also more complicated as originally anticipated. Just as these problems were being solved the researcher fell ill. The result of this sequence of events led to a situation where data could only be analysed after the testing programme was almost completed. A second attempt was made after consultation with a consultant to put the available already tested samples through a further set of tests. It should be emphasised that a specific sample could only be tested once to determine the peak shear strength. All these factors contributed to a rather small number of rock samples that could ultimately be tested.

1.4 Outline of the thesis

Chapter one of this thesis describes the objectives, the motivation for the project as well as the problem of determining the shear strength of joints in rock. This is followed by a description of a literature survey that describes the principal of shear, factors influencing shear strength, results of previous studies and work done by the Norwegian Geotechnical Institute. The following chapter deals with the rock types tested as well as the determination of the shear characteristics. Chapter four describes the interpretation and discussion of the results. This chapter also describes a tool for experienced engineering geologists or rock mechanics engineers to determine the contribution to the angle of friction by the joint surface characteristics. By adding the basic friction angle the total friction angle is obtained. Chapter five describes the classification of shear strength and an estimation of the shear strength by making use of the geotechnical description of the joint surfaces. The next two chapters present conclusions and recommendations. The thesis closes with a list of literature references.

Appendices are available in the back of the thesis in electronic format on compact disc.