Chapter 1

Introduction

1.1 General

Many civil engineering projects are located on or near sloping ground, and thus are potentially subjected to various kinds of slope instability. Slope failures often cause extensive property damage, and occasionally result in loss of life. Figure 1.1 shows an example of the destructive effects of slope failure .In addition to the loss of 10 lives, the direct and indirect cost of landslides in the Conchita Landslide, California, was estimated as millions of US dollars. Road repair and stabilization costs exceeded $10 million. Indirect costs, such as interruption of business, commerce and tourism because of lengthy detours, probably exceeded $5 million. Therefore, geotechnical engineers and engineering geologists frequently need to evaluate existing and proposed slopes to assess their stability. Both qualitative and quantitative methods to analyze slope stability problems have to be used.

Figure 1.1 the 2005 La Conchita Landslide
http://pubs.usgs.gov/of/2005/1067/

In general, quantitative analyses of failure evaluate the slope as if it is about to fail and determine the resulting shear stresses along the failure surface. Then, these stresses are compared to the shear strength of the soil to determine the factor of safety, *F*. The factor of safety varies along the failure surface. Shear stresses on some sections may reach the shear strength first and, as a result, the soil on these particular sections will fail first while the soil on other sections may have a large reserve of excess shear strength. This results in complexities in slope stability analysis. As a result, it is usually assumed that the shear stress along the failure surface is constant. The most popular groups of methods for slope stability analysis are limit equilibrium methods, which do assume constant shear stress along the failure surface. Most slope stability analysis methods use the factor of safety *F* to describe stability. In theory, a factor of safety of one indicates incipient failure, so any slopes with $F>1$ will supposedly be stable. However, there are many uncertainties in analysis such as soil profile, shear strength, groundwater condition, etc. Hence we need to account them by requiring an even larger factor of safety.

The limit equilibrium analysis consists of two steps. It begins with searching for a potential failure surface and calculation of *F* for that particular trial slip surface. The analysis must be performed on the correct surface so that it reflects the proper failure geometry. There are an infinite number of potential surfaces and it may be difficult to determine which one is the real failure surface. In the limit equilibrium analysis's terminology, the real failure surface is called the critical failure surface. Usually the critical failure surface is identified through an informed trial and error process. By analyzing many different potential surfaces and computing the value *F* for each, the one with the lowest value of *F* is the critical failure surface and that *F* is the factor of safety for the entire slope.

Although some slope stability analyses can be performed by hand using a reasonable number of trial surfaces and a thoughtful search pattern, they are ideal candidates for computer programmes. During the past 30 years, considerable attention has been given by several researchers to locate critical failure surfaces. The use of optimization techniques and the finite element method (FEM) is becoming increasingly popular among them. The traditional nonlinear optimization techniques have come across few deficiencies dealing with the limit equilibrium methods. The traditional optimization techniques are mainly calculus based, meaning that they are local search algorithms. Consequently, it is possible that they will yield solutions that are local optimum. Although FEM is powerful enough to bypass many of the deficiencies that are inherent in the limit equilibrium methods, it also introduces complexities limiting its usage to those problems whose detailed progressive failure is required.

Recently, in advent of high performance computers, heuristic optimization techniques have become more popular than conventional optimization techniques. Genetic Algorithm (GA), Particle Swam Optimization (PSO), Fish Swam Algorithm and Ant Colony Optimization (ACO) are some of them that are used to find critical failure surfaces. Among these methods, ACO is considered as one of the popular heuristic optimization methods. ACO is inspired by the foraging behaviour of real ant colonies, and used to solve discrete optimization problems. ACO algorithms are one of the most successful examples of swarm intelligent systems and have been applied to many types of problems in varies research disciplines such as travelling salesmen problems and routing problems. Recently, applications in the field of civil engineering have begun to appear.

In this study, ACO is used to locate the critical failure surface. The Morgenstern–Price formulation for slope stability analysis is used since it is based on mathematically robust foundation in that both force and moment equilibrium equations are satisfied and that no assumption regarding the geometry of the failure surface is required. In addition, no restriction is placed on the positions of the initiation and termination points of the failure surface. Also, the Newton-Raphson method is used to solve the nonlinear equations from the Morgenstern-Price method to find *F*. This way, the numerical strength of the Newton-Raphson method and optimizing capability of the heuristic ACO technique are both effectively utilized.

1.2 Objectives and Scope of the Study

As per the foregoing discussion, this study is conducted to determine the critical failure surface for slope stability analysis by using an ACO algorithm. The objectives of this study are

1) To propose an ACO algorithm for finding the critical failure surface for a given slope.
2) To investigate the validity and effectiveness of the proposed ACO algorithm in solving slope stability problems.

The scope of this study is

1) Homogeneous and non-homogeneous soil conditions are considered.
2) Different geometries of the slopes are considered.
3) The effective stress analysis is considered. However, the proposed algorithm can be used for the total stress analysis as well.
4) Effect of earthquake forces is considered.