Chapter 1

Introduction

1.1 General

Recently, a heuristic optimization technique called ant colony optimization (ACO) has been developed for combinatorial optimization problems. The ant colony optimization mimics the foraging behavior of ant colonies in the real world. An ant colony is capable of finding the shortest path between its nest and a food source without using visual clues. The colony can perform this rather complex optimization task even with a low level of intelligence found in each individual ant. In fact, the efficient foraging behavior is achieved by indirect communication between ants via the use of pheromone. It is well known that ants lay and follow pheromone trails. These simple trail-laying and trail-following mechanisms enable the colony to seek out the shortest path to the food source.

To illustrate how it can be achieved, consider a colony of ants shown in Figure 1.1. In the figure, there are two available paths of different distances between the colony's nest and a food source from which ants may select. At the beginning, the ants will select the

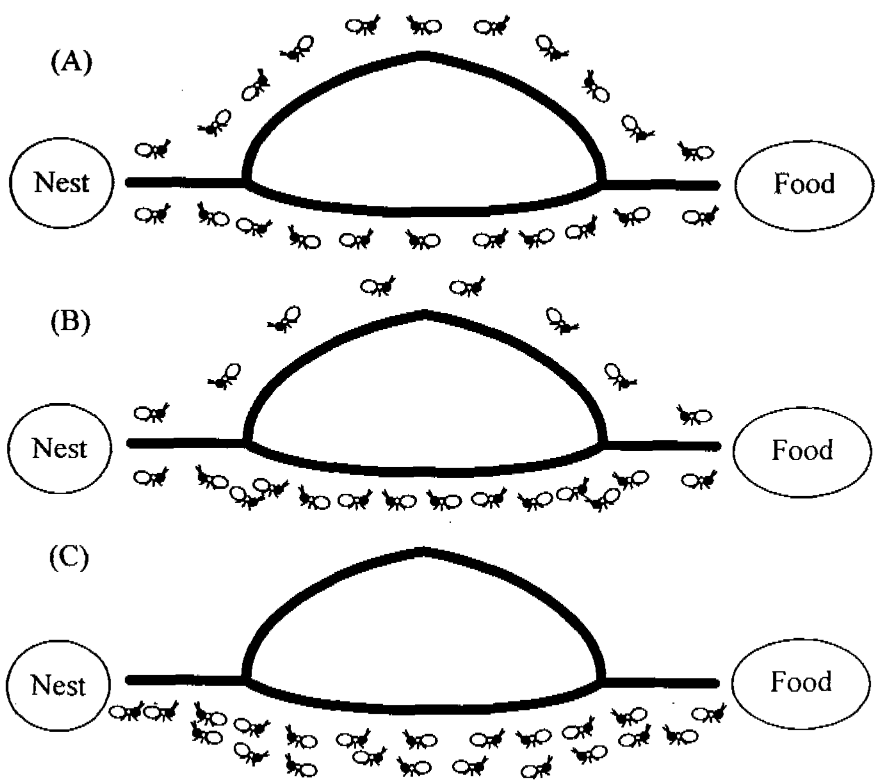

Figure 1.1 Foraging behavior of ants: (A) At the beginning, ants select the longer and shorter paths with equal probability; (B) Pheromone is deposited faster on the shorter path. More ants select the shorter path; (C) Finally, all ants select the shorter path

two paths with equal probability, meaning that there will be approximately half of the ants selecting each path. Since the shorter path requires less time to complete, the ants on the shorter path will be able to, for the same amount of time, complete more rounds. As a result, the quantity of pheromone on the shorter path grows faster than on the longer one. Due to the shorter path's higher pheromone level, more ants will be probabilistically attracted to the shorter path and lay even more pheromone on this path. Finally, the levels of pheromone on the two paths will be so different that virtually all ants will select the shorter one.

It must be noted that pheromone trails established by ants do not last forever but rather they evaporate. This pheromone evaporation is also an important mechanism since it prevents too rapid a convergence towards a sub-optimal path. In other words, it allows a very good path that has not been discovered by ants until after a certain number of trips to overtake those moderately good paths that are discovered earlier. The three aforementioned mechanisms, i.e. pheromone-trail laying, pheromone-trail following and pheromone evaporation, can be artificially simulated by computers and constitute the Ant Colony Optimization (ACO) technique.

In recent times, the ACO technique has been used in several types of optimization problem with satisfactory results. Some examples of ACO applications are the traveling salesman problem, the quadratic assignment problem, the just-in-time sequencing problem, optimization problems for designing and scheduling of batch plants, etc. However, the application of the technique in the field of civil engineering is found to be rare.

Most of practical structural design optimization problems consider only sizing optimization, which is basically combinatorial optimization. In this study, the ACO technique, which has been designed for combinatorial optimization problems, is applied to solve structural sizing optimization problems. To this end, the structural sizing optimization problems under consideration have to be prepared in a suitable way that fits the ACO technique. After that, a simple ACO algorithm can be implemented. To show the validity and efficiency of the proposed algorithm, sizing optimization problems of truss and frame structures are solved in this study. For comparison, some of the problems are also solved by a genetic algorithm (GA). In addition, the results obtained by the proposed algorithm are compared with those from the literature. Finally, the performance of the proposed algorithm is discussed.

1.2 Objectives and Scope of the Study

At present, in order to solve structural optimization problems, there are many available algorithms for researchers to choose. Some famous algorithms are such as genetic algorithms (GAs), simulated annealing (SA), evolution strategies (ES), tabu search, etc. However, algorithms based on social insect's behaviors have been popular among scientists and researchers in recent times. This study aims to utilize the efficiency and simplicity of one of these algorithms, i.e. the ACO algorithm, to structural optimization problems. The objectives of this study are

1) To propose an ACO algorithm for structural sizing optimization problems.
2) To investigate the validity and efficiency of the proposed ACO algorithm in solving structural sizing optimization problems.

The scope of the study is

1) Only sizing optimization is considered. Shape and topology design optimizations are not included.
2) Only discrete design variables are considered. Continuous design variables can be used if they are converted into discrete variables.
3) Linear elastic analysis is considered.
4) Constraints are provided in form of allowable values. Functional constraints are not considered.
5) Two-dimensional truss and frame structures are considered.