Chapter 1

INTRODUCTION

Blasting is the most common method for breaking rocks in mining. The total consumption of explosives in 1995-96 in India was 260,000 tonnes, of which coal mining alone accounted for nearly 70%. The cost of drilling and blasting is 25% of the total cost of coal production, of which the direct cost of explosives is about 5%. In hard rock mining, the cost of drilling and blasting is about 40% of the total production cost. There is scope for cost reduction at surface mines through optimised blast designs.

The primary objective of blasting at surface mines is to create a well fragmented muckpile suitable for the loading equipment deployed in the mine, at the least cost while ensuring minimum damage to the environment. A blast is said to be optimal when the total cost of drilling, blasting, loading, hauling and crushing is minimised. Several factors, including safety and legislative restrictions, affect the design of a blast and a compromise is often necessary to incorporate the effects of these constraints in the optimal blast design.

The parameters to be incorporated in a blast design can be broadly categorised into 1) explosive characteristics, 2) rock characteristics, and 3) blast geometry and initiation sequence. Rock characteristics over which the blast designer has no control are called uncontrollable parameters whereas explosive characteristics, blast geometry and initiation sequence, which are to be designed considering the constraints and the geo-mining conditions of a mine, are called controllable parameters.

Blast design in Indian mines is mostly based on the method of trial and error. The blast parameters are modified till the design produces satisfactory results. Sometimes the mines may not be able to achieve the desired results and the resultant blasting problems are referred to research organisations. The common problems at surface mining are boulders (oversize fragments), fines (undersize fragments), toe, backbreak, hard digging, ground vibration, air overpressure, and flyrock.

A comprehensive review of literature has revealed that cratering, single hole test, empirical, field trials, and computer simulations are some of the approaches to blast design. In recent years, three significant developments have taken place in blasting technology such as usage of large diameter blastholes, replacement of cartridge explosives with bulk explosives, and availability of accurate and flexible initiation systems. These developments have altered significantly the scale of blasting operations and the characteristics of the explosives used.
Early approaches to the design of blasts (Langefors and Khilstrom, 1963) have been found to work less effectively for the large scale blasts commonly used in modern mining operations (Scott et al, 1993) Blast design has now become more challenging and important. Recent monographs (Atlas Powder Company, 1987, Konya and Walter, 1990, Berta, 1990, ICI, 1993, Persson et al, 1994, Jimeno et al, 1995) present theory and practice in blast design. However, available methods for blast design are neither rigorous nor adequate and most mining operations do not give sufficient importance to the blast design for particular operations. Thus the need for a systematic approach to arrive at optimum designs was identified.

Several methods including small scale physical models, analytical and numerical models, reduced scale field tests, and full scale field tests have been adopted in blasting research. Physical models using small blocks of rock (or other material) with small quantities of explosives (Ruslan et al, 1983, Singh and Sastry, 1987, Winzcr et al, 1983, Bhandari and Badal, 1990, Armstrong et al, 1993) have proven invaluable in the study of mechanisms of rock breakage, the effect of geometry and discontinuities on fragmentation. However, the practice of predicting full scale blast results on the basis of small scale experiments should be viewed with caution as the essential conditions of the similarity are frequently ignored. Analytical and numerical modelling (Adams et al, 1985, Heuze et al, 1993, Paine and Please, 1994, Munjiza et al, 1994) attempts to model the explosive-rock interactions involved in rock blasting. This is essentially a research tool in rock blasting and is not mature enough to apply for real blasting situations. Reduced scale field tests (Dick et al, 1973, Ash, 1973, Smith, 1976, Stagg et al, 1990) were conducted at 5-10% of the full scale so that a complete screen analysis of the muck pile could be used to determine the influence of various design parameters on rock fragmentation. Blast design can utilise the scientific knowledge available from the results of the model blasts and reduced scale field studies.

Compared with other rock engineering problems, blast design is complex not only because of the uncertainties in the rock mass properties but also the uncertainties in the explosive properties and the scatter of delay timings. Furthermore, blasting is a dynamic phenomenon which is obviously more complicated than static problems. The mechanisms of rock blasting are not clearly understood. For these reasons, a study based on field investigations and analysis of field data is considered to be the most appropriate method to address the blast design problems.

A large number of investigations were carried out by the author at various surface mines to solve a variety of practical problems. Most of these mines were located near villages, railway lines, public roads and other surface structures. Blasts were designed and implemented in these mines to exploit the mineral resources profitably with minimal environmental
disturbances. The field data have been analysed in depth to develop a methodology for blast design at surface mines, especially for selection of explosives, assessment and control of environmental effects, and determination of blast design parameters. Considering all the factors which interact and the various processes involved, a new approach called the guided approach is proposed for blast design at surface mines. The guided approach was then applied at three surface mines.

This thesis describes the guided approach to blast design and its applications at three surface mines. It is divided into eight chapters. Chapter 1 introduces the subject, defines the problem and clearly sets the objectives of the research work. Chapter 2 reviews the literature on the theory of rock breakage and the various approaches to blast design. The limitations of the existing approaches are briefly discussed and the need for a new approach is identified. The new approach called the guided approach, presented in Chapter 3, discusses the methodology and strategy to arrive at an optimum design. This methodology is devoted to bench blasting for surface mines and does not cover special applications such as cast blasting, trench and ramp blasting, and presplitting. Chapters 4, 5 and 6 are the elements of the guided approach. Because of the volume and their importance in blast design they have been presented in separate chapters. Chapter 4 deals with the selection and evaluation of explosives with particular reference to Indian mines. Chapter 5 discusses the techniques to assess and mitigate blasting hazards through blast design. Chapter 6 suggests the methods to determine the important blast design parameters. The data used for Chapter 5 and 6 were taken from the author's publications and unpublished reports. Chapter 7 presents the case studies where the guided approach was applied successfully. Finally, Chapter 8 summarises the results and findings discussed in various chapters and recommends the areas for further work. The computer programs written based on the suggested methods, norms and standards for ground vibrations and air overpressure, a list of author's publications on the topic of this thesis and other relevant information are presented in Appendix.