CHAPTER 1

Introduction

1.1 General

Mining has played a significant role in the development and running of other industries. Wherein coal mines have played an essential role in generating electricity and producing metal, cement, chemical, etc. The consumption or the actual supply (including import) of coal has increased from 807.721 million tons in 2015-16 to 955.307 million tons in 2019-20, which indicates that the demand of coal is increasing significantly. The increasing demand of coal has set tremendous pressure on the mining engineers to meet target production. Most of the production comes from the Opencast mines, whereas the contribution of underground mines is significantly low.

Opencast mining is a very efficient mining method for extraction of the minerals with high production. The opencast mining generally results in the production of large amount of waste material. The overburden dumps are being formed by the loose and blasted overburden material. The rate of the growth of opencast mines are increasing exorbitantly in recent years to meet the future needs of coal. The mining engineers and mine planners have to go for enhancement of the production from the existing projects by deployment of mega size Heavy Earth Moving Machineries (HEMMs) as well as to extract the coal seams at higher stripping ratios. The continuous increasing production leads to higher amount of overburden generation.

The removal of overburden is the first step in the opencast mining to expose underlying coal for excavation. Being a non-marketable product (overburden), it has to be removed, dumped safely and economically. It can be dumped both internal dump as well as in the form of external dump. Internal dump is the most economical and environment friendly waste dump management being adopted in mega opencast projects. Internal dumping methods are the most economic waste dump management method operating the major opencast coal projects in India (Rai et al., 2012).

In large opencast coal mines, the dragline machine is used to remove the overburden to expose the coal for the production. The dragline primarily side cast the overburden material inside the pit and forms an internal dragline dump. Dragline is primarily used where coal seam is at lower depth along with relatively flat dipping and the ground surface should be horizontal and a wide area should be available to extract the mineral in a series of strips (Westcott, 2004).

The Dragline excavates overburden material and side-cast to form an internal overburden dump. It sits above the mine dump or on the highwall side and excavates the material in front of itself and it dumps the overburden on the low-wall or spoil side of the strip, thus uncovers the coal seam underneath. A heap of overburden material is formed by the dragline between the working face and the main dump (Figure 1.1). In some of the opencast mines a coal rib is left in between the internal waste dump and the mine benches as shown in the Figure 1.1. Extraction and transportation of coal is done through the space between the coal rib and the mine benches. Figure 1.1 shows working of a dragline in large opencast coal mine having coal rib and internal dump slope.

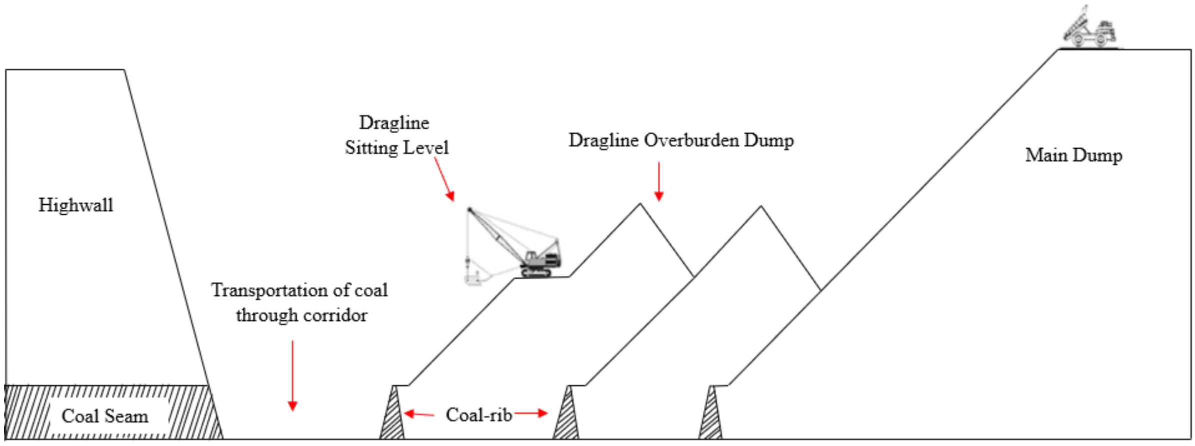

Figure 1. 1 Schematic diagram of a dragline working.

As working depth of opencast mines increases with time, removal of overburden material increases. Increasing volume of waste material create a challenge in front of engineers to construct a safe dragline overburden dump slope. In order to construct safe dragline dump, a coal-rib is left against the dragline dump, which increases even more overburden waste material holding capacity of dragline dump and enhances the stability of the dump. The coal is transported through the corridor created between the coal-rib and the mine benches or highwall, from where the coal has been extracted. The coal rib restricts the movement of the dump and helps in the placement of the maximum possible overburden material in the mined-out area. The working face, from where the extraction of coal is going on also lies in between the coal rib and highwall, so in any case if coal-rib fails, the waste material will flow into the working face and may lead to the loss of men and machinery. If coal rib is stable but dump slope unstable, then also the failed material moves into the working area. This may also lead to stoppage of work temporarily or permanently (Gupta et al., 2014; B. G. Richards et al., 1981).

There are broadly two types of parameters; geometrical parameter and geotechnical parameters. The geometrical parameters include; overall dump height, overall slope angle, individual bench height, individual bench angle, bench width, thickness and height of coal-rib and strata dipping or inclination of foundation. The geotechnical parameters include; strength parameters (cohesion and angle of friction), modulus of elasticity, compressive strength, maximum dry density, optimum moisture content, unit weight, etc. The stability of dump slope depends on strength properties of the dump material and geometry of dragline dump. The various geo-mining parameters and geotechnical properties of dump are not constant; it varies with depth and locations. Therefore, the effect of these parameters on internal dragline dump is not uniform.

The stability of a dragline dump supported by a coal rib depends on various parameters, such as the shear strength of the coal rib and foundation interface, the dimension of the coal rib i.e. width of coal rib at the top and its base, the distance of bench from the coal rib, the height of the dragline dump, etc. Subsequent build-up of high horizontal stresses in the rib, either due to accumulation of water or due to over dumping, causes the rib to fail which can lead to the dump failure.

Large waste dumps are being formed by loose and blasted overburden material. The chance of failure of dump slope is very high, particularly in rainy season. Dump failure may lead to stoppage of the work temporarily and accidents causing loss of men & machinery. With increasing adoption of opencast mining method for coal at higher stripping ratio, the problems associated with instability of dump slopes have increased significantly. Failure of improperly constructed dump is likely to cause risks for mining equipment and personnel and extensive loss of production. A number of cases have been reported in literature where the dump failures have caused substantial damage and interrupted the production (Bowman and Gilchrist, 1978; Richards, 1981; Okagbue, 1987; Speck et al., 1993; Ulusay et al., 1995). While very low height and flat dump could be ideal for stability, it would not only occupy large ground space but also not economical from mining point of view. Therefore, one should look properly the design parameters of internal dump slope (Chaulya et al., 1993; Chaulya, 1997; Kasmer et al., 2006). Therefore, the design of the coal rib of internal dragline dumps should be done in a proper way. Along with design of coal rib, profile of dragline dump should also be designed carefully, so that it can ascertain stability as well as safety of the dragline dump slope (Bharati et al., 2020, 2021a, 2021b; Khandelwal et al., 2015; Steiakakis et al., 2009; Kasmer et al., 2006; Kainthola et al., 2011; Sharma and Roy, 2015; Dash, 2019).

The prediction of stability of slope is a very challenging and cumbersome process, it requires various input parameters. The prediction technique should be adaptable to most of the slopes irrespective of geology and rock type. In most of the techniques, the Factor of Safety (FOS) is used for generalizing the whole process of the slope stability analysis, which describes the overall strength and vulnerability of the slope (Renani and Martin, 2020). There are several methods to perform the stability analysis such as; Limit equilibrium method (LEM), Numerical methods and statistical methods. Numerical methods have shown better accuracy for the slope stability problems and have been widely adopted these days by researchers. There are several methods in numerical simulation such as Finite element method (FEM), Finite difference method (FDM) and Discrete element method (DEM). FEM is the most appropriate method for the analysis of the complex slope stability problems. These numerical methods include simulation of the slope models, which is a time taking process and requires high processing computers for the simulation.

These days statistical methods have also performed well in the prediction or estimation of stability of slopes. These methods incorporate the data and by analyzing the data predict or calculate the desired output. There are several statistical methods that has been adopted for the statistical stability analysis of the slope such as; Artificial neural network (ANN), Multiple linear regression (MLR), Random Forest etc. In recent years, various machine learning tools have been implemented successfully in several slope stability projects, whether it was for natural or artificial slopes. The artificial neural network (ANN), being one of them, has been considerably used in solving various slope stability cases (Alimohammadlou et al., 2014; Verma et al., 2016; Erzin and Cetin, 2013; Pradhan and Buchroithner, 2010; Pradhan and Saeid, 2010; Ray et al., 2020). Also, there are several documented cases of the use of multiple regression analysis (MRA) for stability analysis (Erzin and Cetin, 2013; Rahul et al. 2015; Chakraborty and Goswami, 2017). The multiple regression analysis (MRA) is a statistical technique that mainly derives a relationship between the output variable and the input variables. This technique has also been found to be useful for solving slope stability problems.

Due to higher production demands, mining is going deeper and the height of these dumps are increasing. With the increasing dump heights risk of instability is also increasing, therefore a rigorous study is needed for the stability analysis of the dump slope. The primary challenge is ensuring the stability of the dump slope with maximum production. The problem of stability could be solved by equilibrium methods, numerical methods or the statistical methods and all these methods are associated with certain limitations. Therefore, the challenge is to identify which method is best suitable to perform the stability analysis with maximum accuracy. (Chaulya, 1997).

1.2 Research gap and motivation

Several research have been performed regarding stability analysis of the dragline dump slope and most of them are using the limit equilibrium method (LEM), which is primarily performed by using uniform mechanical properties and simple geometries of the dump slope. LEM has many limitations as it takes so many assumptions prior to simulation. Therefore, finite element method has been used in this research work in order to maximize the accuracy of the stability analysis. FEM is widely used and accepted by most of the researchers, it gives better results in case of complex geometries as well.

Stability analysis of the dump slope is also gets compromised as the uncertainty within the geotechnical properties is unnoticed mostly. It can be easily observed during the field or laboratory testing that in reality rock or overburden dump material possess heterogeneity, which comes differently in simulation in comparison to the reality. Therefore, probabilistic approach has been used along with numerical simulation, which helps in incorporating uncertainty involved in the geotechnical properties. However, its implementation is restricted to the limited availability of data and requires additionally prolonged computational time in simulation of dump slope models. Sufficient number of data is required for the parameter, which has been taken as uncertain parameter, so that a statistical distribution function for that particular parameter could be generated for a reliable probabilistic or statistical simulation. The data for that particular parameter could be generated from field and laboratory test to obtain real results.

Several cases of dump failure have happened in opencast mines and have led to huge loss of men and machinery and considerable damage to the mining area along with the stoppage of production (Speck et al., 1993; Kasmer et al., 2006; Singh et al., 2014). Therefore, the design of the internal dragline dumps should be done in a proper way keeping the safety of men and machinery (Sharma et al., 2011). Geometrical and geotechnical parameters play a very crucial role in the stability of the dump slope (Kainthola et al., 2011; Behra et al., 2016). With the increasing demand, mining has gone deeper and deeper and will go on further, which requires consistent dump stability analysis as height and volume of overburden material of dump slope will increase. In this case, quick stability assessment method needs to be done because individual slope stability assessment methods are cumbersome and time taking method, therefore safety charts have been devised. The safety charts could be proved handy in quick identification of stability status of the dump slope.

Advanced machine learning (ML) models for stability analysis can be created using the data produced by the numerical analysis. Artificial neural network (ANN) is a popular example of ML approaches that have been utilized to tackle challenging nonlinear multivariable geotechnical issues, such as analysis of slope stability. ANN approaches are developed to establish a relationship between the safety factor and its influencing parameters from recorded data. It has been observed from the previous researches that ML approach should be used frequently to handle more complicated slope stability problems.

1.3 Objective of the study

The objective of the study is to provide a methodology for quick assessment of internal dragline dump stability using finite element method, probabilistic analysis, and statistical method. The following objectives have been considered for the present study:

I. To understand the effect of geometrical and geotechnical parameters on stability of dragline dump slope using numerical simulation.
II. To propose safety chart for dragline dump slope stability for geometrical parameters.
III. To develop a stability classification system for dragline dump slope.

IV. To develop a slope instability prediction model for dragline dump slope using Artificial Neural Networks and obtain the relative importance of the stability governing parameters.

1.4 Scope of the study

Several studies have been performed in assessing the stability of overburden dump slope, which is mainly governed by the geotechnical properties and geometrical parameters. However, work on dragline dump slope is limited. The stability of dragline dump slope depends on seam gradient, thickness of coal-rib, width of coal-rib, slope and height of dragline dump, etc. Understanding the significance and interactions of all the parameters are essential for identifying the dragline dump slope hazard potential.

The objectives of the studies have been achieved by field and laboratory experiment, Numerical modelling, one and two parameter sensitivity analysis, probabilistic analysis, and statistical analysis. Accordingly, following scopes were identified for the study:

I. An extensive literature review has been done on dragline dump slope stability.

II. Laboratory test and field experiment have been carried out to determine geotechnical properties of overburden material.

III. Simulation of numerical models by deterministic and probabilistic methods for the stability analysis of dragline dump slope.

IV. One parameter sensitivity analysis has been carried out to determine the important dragline parameter for safety chart

V. Two parameter sensitivity analysis has been carried out to determine the important dragline dump slope parameter and properties for classification system.

VI. ANN has been used for the prediction of stability of dragline slope

1.5 Organization of thesis chapters

This thesis is divided into the following eight chapters:

Chapter 1 includes a basic introduction about dragline dump slope in opencast coal mine, the major factors related to soil slope failure, methods for slope stability analysis, scope of the work and objectives of the study.

Chapter 2 reviews related literature concerning dragline dump slope in India and abroad, factor affecting dragline dump slope stability, types of failure in dragline dump slope, geomaterial and use of probabilistic analysis, various slope classification and Machine learning techniques.

Chapter 3 includes information on site selection for data and sample collection, in-situ and laboratory tests conducted for various geotechnical parameters of the overburden dump material.

Chapter 4 includes statistical analysis of the data generated from in-situ, laboratory tests and literature survey, development of a numerical model using probabilistic analysis, formulation of risk chart for dragline dump slope using most important slope parameters.

Chapter 5 includes the development of slope classification for dragline dump using geometrical and geotechnical parameters and validation by case study of dragline dump slope.

Chapter 6 includes the utilization of machine learning techniques like Artificial Neural Network for developing a highly accurate prediction model for dragline dump slope for the most important parameters affecting the stability of the dragline dump slope.

Chapter 7 provides the conclusions made out of this research and future recommendation.