1 INTRODUCTION

Drilling and blasting is made up of groups of tasks, which are performed to produce broken rock with specific fragmentation and muck pile shape & displacement while ensuring that safety, statutory requirements and/or environmental compliance are met. Procedures need to be defined for carrying out drilling and blasting to obtain desired results. Data collection: pre-blast, during the blast and post-blast is critical to the blasting process -- for blast design, for prediction of impacts, for taking corrective steps at execution stage and for further analysis and planning purposes.

Generally blasting related information is poorly managed with disjointed and unrelated information technology systems managing parts of blasting data. Data is often moved from one system to another, sometimes manually. A data management system not only ensures information storage, but also acts as an intelligent system for optimization of blasting and overall operation. The review and analysis of past data can improve blast design, blast execution and help in the achievement of desired blasting outcomes and downstream productivity, and process improvement by adjustment of drilling and blasting parameters. Based on the database and its search and analysis capabilities, the system can provide opportunities for taking corrective steps by changing explosive charge distribution, initiation timing and sequence for controlling fragmentation size, flyrock, and ground and air vibrations.

This paper shows importance of data collection and analysis. A case study has been provided where data from 1995 till date has helped a limestone open pit mine in improving drill factor from 45 tons/m to 75 tons/m, breakage of limestone from 6.5 tons/kg to 14 tons/kg thus reducing costs by 50% while improving crusher productivity from 764 tons/hour to 932 tons/hour and controlling vibration, flyrock and dust.
tions are either recording data in registers and/or are using excel sheet. Difficulty is about customizing imported software and also updating the database. Further, blast execution is not different in similar countries while using similar explosives and initiating systems. In general, mines are keeping blast data in paper based system and have generally not benefitted from recent technology advancement. Drawbacks of the system include that record retrieval is time consuming, record cannot be used for analysis, and insufficient data are recorded. Advantage of using information technology data base are systematic storage of data, retrieval of data over a long time period, analysis of data for improving efficiencies, automated reports, view and analysis at distant location if desired. In general separate reports have to be prepared/ submitted to different regulatory authorities, to management and also needed for own requirement of mine operators. This paper discusses how computerized data collection and analysis can provide improved blast accuracy and performance achieved through a more intelligent blast design, made possible by combining with distinct data base. This is accomplished by focusing on key performance indicators derived from the historical performance of drill and blast events. The searchable data base of blasting information drives incremental improvement in performance.

2 DATA MANAGEMENT

A data management system not only ensures information storage, but also acts as an intelligent system as an aid for blast design, prediction of impacts and analysis. Database can be integrated with mine planning, drill guidance, field survey, load design parameters and post-blast evaluation (Figure 1). Database is foundation for optimization of blasting and overall mining, tunneling or quarrying operation. Based on the database and its search and analysis capabilities, the system can provide opportunities for getting dynamic drilling and blasting parameters, vibration constants and predictions, flyrock predictions, fragmentation size predictions. This information helps in adjustment of drilling and blasting parameters based on optimized results.

Besides measured parameters related to blasting parameters, explosives accessories, geotechnical information, environmental information are required for planning and design of blast block (Birch, et al., 2002; Hutchins, 2004; Bhandari and Bhandari, 2006, Bhandari, 2011). Blast data management system stores blast details, blast parameters, blast pattern, face profile, explosive consumption, charging details, costs, weather information, pre-blast survey, post-blast evaluation data, fragmentation information, photograph(s), videos, accidents, misfires

Figure 1. Blast information integration

flyrock, vibration record and information for vibration analysis. Video and photographic records also provide opportunity to analyze displacement and flyrock. These also indicate face movement and hole by hole behavior. Integration of the following also needs to be accomplished:

- Vibration monitoring results.
- Blast simulation and airblast and ground vibration reinforcement.
- Flyrock and safe zone for personnel and equipment.
- Fragmentation size distribution.
- Blast dust plume movement.

Data obtained from blast hole face profiling tool, vibration prediction tool, and direct data link to a database incorporating all the major manufacturers products and an interface allows the user to add new product ranges and create custom products. Directly import drill patterns and pit shells from the mine planning packages. By linking with geological data/chemical data the blast block can provide quality assessment.

Performance and cost of blasts can be monitored and Key Performance Indicators can be determined. Appropriate blast designs for particular areas of mine and different zones can be identified. Optimizing the blasting process involves drilling accuracy and efficiency, profiling of exposed faces for mining applications, tailored loading explosives according to face profile and rock conditions at depth, and designing proper parameters, delay timing and initiation sequence. Reports can be generated as per various requirements of the organization or statutory authorities. Blast records must be held for statutory purposes and would be useful in case of litigations.
3 CASE STUDY -- ADITYA LIMESTONE MINE

Aditya limestone openpit mine belongs to Ultra Tech Cement Ltd group which has several limestone openpit mines spread across India. Aditya mine is designed to produce 6.6 million tonnes limestone per annum for its cement plant, situated around 2 km away (Parihar et al, 2009). The ore to overburden ratio is 1:0.33. Thus, total rock handling is around 9 million tonnes per annum. Presently, there are two working pits. The mine is surrounded by small villages.

Figure 2. Blast result in Aditya Mines

Geology: Aditya Limestone deposit belongs to Nimbahera limestone formation: limestone, shale and clay are the major rock types. Limestone is fine grained, thinly laminated to massive in structure. Aditya limestone mine deposit is highly jointed. The joints are multi-directional. Some of them are filled with overburden soil and clay. The deposit was subjected to structural disturbances of moderate intensity as evidenced from numerous minor and major folds and joints.

Broadly, the structure of the entire deposit can be classified as a synform. In spite of the above folds, study of dip and strike readings indicates N - S trend with maximum of 10° deviation on either side. The amount of dip varies between a narrow range of 0° to 20°. Dip direction changes from East to West due to folding. There is plunge of about 5° in strike direction.

Mining: Mining is carried out by fully mechanized open pit mining method. The working pit is below the general topography of the area. Working pits have been developed with working benches of 9.0 m. height. At present, the work is going on in three benches. Drilling is done with the help of ROC L6 and IBH-10 drill machines of 100mm-115mm diameter. A set of about 25 holes is blasted. Excavation and loading operations are carried out by hydraulic excavators. At a time two excavators are used for this operation. Transportation of limestone from working face to crusher hopper is carried out in 35/60 tonner dumpers. Before crushing, the limestone from crusher hopper is passed through grizzly screen or screening out intrusive clay.

The mines have kept blasting records since the beginning of mining operations in 1995, initially in hand written format and thereafter have been maintaining records in Excel sheet format (Figure 3 & 4) for its blasting operations, explosive consumptions, drilling performance, blasting costs. These data show considerable improvement in blasting performance and at the same costs have also reduced. This has been possible in spite of much increase in costs of explosive, accessories and labour and other input. Continuously several new techniques have also been adopted with indigenous and local methods.

Figure 3. Written records of each blast

Figure 4. Records using Excel Sheet
and tools have helped in achieving the above stated results. An example of charging with indigenously developed wooden spacers for giving airgap (Figure 5).

Blast records from 1995 till date has helped the mine in improving rock breakage of limestone powder factor from 6.5 tons/kg to 14 tons/kg (Figure 6) drill factor from 45 tons/m to 75 tons/m (Figure 7), thus reducing costs by 50% (Figure 8) while improving crusher productivity from 764 tons per hour to 932 tons per hour and controlling vibration, flyrock and dust.

1. 2.5 M.
2. 7.5 M.

Funnel

Stemming

ANFO

Booster

Air Deck

ANFO

Booster

Figure 5 Use of airdeck Wooden spacer

Figure 6. Tonnage per kg of explosive improved

The mine is now using blast related information data management system for record, analysis and reporting. This indigenously developed system is reliable, easy to use, stores large data and provides retrieval and analysis of the stored data and also provides costs, weather information, pre-blast survey, post-blast evaluation data, fragmentation information, photograph(s), videos, accidents, misfires, flyrock, vibration record and information for vibration analysis records (Figure 9). Software also provides opportunity to analyze displacement and flyrock, back break/over break records to be maintained and analyzed.

4 BLAST INFORMATION MANAGEMENT SYSTEM (BIMS)

Blast Information Management System (BIMS) provides information to meet the strategic and operational needs for planning, controlling and decision-making for optimizing mining operations (Bhandari and Bhandari, 2006). BIMS provides methods to store, manage, document and retrieve drill and blast related information. The system stores blast details, actual blast parameters, blast pattern, face profile, explosive consumption, charging details (Figure 9), recorded videos and stored in the database can also be used for observing face movement and hole by hole behavior.

The stored blast information data can be retrieved quickly and easily. Performance and cost of blasts can be monitored and appropriate blast designs for particular areas or different zones can be identified. The data management and retrieval is easy and simple to use which can be carried out in a few minutes.
helps in optimizing various operations. Readily available past data in a logical format and blasting data analysis tools are the key features of the database.

The database can be extended to integrate with other systems such as ERP, CMMS etc. If the software is operated in conjunction with a comprehensive monitoring program, it can contribute to the efficient running of an operation and reduce environmental effects to a minimum. Importing data using .csv file, Excel and other popular mining software makes it is possible to reduce input work. Entered data can be edited through Edit Parameters.

Many central and state agencies, concerned with Explosives Security, Mines Safety and the Environmental Protection (DEP), are increasing their expectations for strict accounting of inventory and blast documentation. Blasting company executives and managers are now facing the possibility of incarceration, fines and suspended operations if their documentation is not in order. The database can be tailored according products and practices, to customer requirements and can be maintained.

This database has also searching options using which the user can look for the records of blasts as per his defined criteria. Currently, the software uses the following criteria for the search option: between dates, by performance of explosives or initiating system, by vibration limits, by fragmentation size, by location of blasting zone or accident etc.

Presentation of analysis of data, compliance reports suitable for regulatory bodies, archiving and viewing of data at distance location, costs can be developed. Reports suitable for Occupational Health and Safety (i.e. incident reports) can be compiled. Key performance indicators are derived.
er cost all as separate entity, so that each & every step of the mining activity could be optimized by using this information. Mine has to provide returns to regulatory authorities PESO, Indian Bureau of mines, Director General of Mines regarding consumption of explosives quarterly, monthly and yearly. Besides management also want end of the month reports. Many records have to be maintained for statutory requirement. Stored information also helps in providing information in cases of litigations.

The database application is password protected as such restricting the use of the software. The database is protected; as such no unauthorized access to the data is possible.

Inventory control & stock management gives knowledge of amount of explosive or initiating devices available for the blast is left after the blast. This could help in keeping a track of consumption of material in the mine and to maintain the quality of explosives as not to have too little or excessive stock.

The program also records all the important analysis data like those of vibration monitoring, fragmentation analysis etc. Further functionalities like VOD measurements can be added.

5 BLAST DESIGN AND PREDICTION TOOLS

Based on data base information about geotechnical, environmental requirements, planning outcome a separate Blast Design module can design blasts. Design software can create and edit drill patterns using geotechnical and environmental information data base. Blast patterns are individually designed for every blast block taking into considerations for quality. Based on past best practices it provides blast calculations, specific blast design and blast hole data, priming details, hookup and timing analysis calculations. Charging appropriate quality and quantity of explosive and using appropriate initiating system is provided. This design has already taken into consideration ground vibration, flyrock, dust limits, fragment size distribution and other requirements while providing blast design.

After drilling has been carried out actual hole positions, dip and face profile are measured. Design data is separated from measured data. Prediction tools are again used to see if any of the limits are exceeded with regard to ground and air vibration limits, flyrock limit etc. Software may use information to create charge standards to design specific hole by hole explosives loading and create load sheets according to geotechnical zone characteristics and results required.

The software can be used to assess the likely impact or effect of a particular design. Vibration reinforcement analysis (Richards and Moore, 1995) (Figure 12), flyrock predictor (Richards and Moore, 2004) are used to see if charging and initiation timing and sequence need to be changed to meet with flyrock, fragmentation, vibration limits. This is in conjunction with field observations, experimentation and monitoring.

Simulation of initiation design including, angle of initiation, direction of movement are given. Design initiation sequences for electronic detonator systems and applying timing to defined zones to enable multiple independent deck firing.

Figure 12. Reinforcement of vibration before blasts helps in changing delays

6 CONCLUSIONS

Database connects all information related to blasting operation to provide reporting, trends and analysis. Custom graphs and reports reduce work for providing reports to any desktop and can be fully customizable to meet key production indicators, and daily reports. Software based data base provides valuable time for engineering and mining professionals by integrating disparate mining data capture software systems and removing dependencies on Excel spreadsheets. This information stored and analysed helps in better control and optimization of mining operations. Data base helps to quickly respond to information and remain successful in today’s competitive market place. Web based versions and tablet PC would make data acquisition easy.

Use of database helps in improving blast efficiencies and demonstrate that an improvement has been achieved there needs to be a comprehensive measurement system, which is capable of setting baseline, and then tracking the changes made to the process.

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