A. SINHA
and
V. K. SINGH

Emerging technology in surface mining and environmental challenges

Introduction

India is richly endowed with huge deposits of useful minerals such as coal, iron ore, limestone, bauxite, lignite, etc. It presently ranks second in the world in coal production and fourth in the world iron ore production. It has huge deposits of limestone. It has reasonably large deposits of bauxite and lignite.

Surface mining has contributed in a big way to global mineral production since the last four and half decades. Currently, surface mining dominates the global mineral production scene with a share of nearly 80% of the solid mineral production (including sands, gravels and quarried stone). Increasing scale of operations to exploit lower grades from increasing depths has been the key trend and this has been facilitated by developments in surface mining equipment, which have grown bigger and better. The Marion 8200 dragline with 88 m^3 bucket, which can produce some 40 Mt/y of coal by shifting more than 70 Mt/y of overburden. Shovel buckets of 20 to 30 m^3 capacity have now become commonplace fixtures in surface mines around the world. While the 218t dump trucks has been the largest twin-axle dump truck commercially available for the past decade, due largely to constraints in tyre capacity, the emergence of Haulpak's 930 with a payload capacity of 258-281 t, fitted with the world's one of the largest off-highway radial truck tyre from Bridgestone. Innovative equipment, such as the surface continuous miners, have got its market for themselves and made inroads into mining areas where close proximity to settlements prevent large-scale blasting. Now a days in the limestone sector in India the surface miners are being used in a big way.

India produces around 150 million tonnes of cement annually. The installed capacity for cement in India at the end of 2006-07 was 166 Mty. It produced around 150 Mty in 2006-07. Bauxite mining for production of alumina/aluminum and lignite mining for power generation are likely to see considerable growth in the current Five Year Plan.

The information technology has also made its presence felt in the surface mining industry. The prospects of complete mine automation is no longer a distant dream. The application of GPS-based truck dispatching systems and computer-aided mine excavation systems hold out exciting prospects. The driverless truck systems are also available.

Environmental issues pose a threat to surface mining developments worldwide. The surface mining industry needs to show the best environmental management in surface mines. Durgmanwadi mine of Indian Aluminium Company Limited became the first bauxite mine in the world to receive ISO 14000 certificate, the international standards for environmental management. Now a days, a number of mining are having ISO 14000 certificate.

Coal/lignite surface mining

The geological coal reserves of the country are estimated at 245.7 billion tonnes (Bt) as on January 2004. Out of this, proven reserves are 91.631 Bt while 116.174 Bt are indicated reserves and 37.9 Bt are inferred reserves. Globally, the coal accounts for 26% of the primary energy consumption, whereas in India, it has a share of 46%.

The Jharia coalfield, in Bihar, has the highest concentration of seams containing mostly metallurgical coal reserve in the country. The coalfield has been exploited by both opencast and underground methods of mining over many decades. Neyveli lignite belt in Tamil Nadu, is the largest lignite bearing area in India. Now the lignite is being exploited in a big way with private government participation in Rajasthan and Gujarat.

With the recent spurt in opencast coal mining activities, more mines were opened with dragline deployment and surface miners. The Piparwar opencast coal mine is the first Indian coal mine to have the inpit mobile crusher. The surface mining segment of the Indian coal industry can rightfully claim a special status in the evolution of coal production in recent years.

Production of coal in India, the third largest producer of coal in the word, was 432 million tonnes by the end of the 10th Plan period (2006-07). Out of this, around 400 million tonnes were from the state-owned Coal India Ltd (CIL) and SCCL and around 32 were from captive mines. Around 85% of country's production is from opencast mines. As per the

Dr. A. Sinha, Director and Dr. V. K. Singh, Scientist, Central Institute of Mining & Fuel Research (CIMFR), Dhanbad, Jharkhand

Expert Committee projections, the country is likely to produce 680 million tonnes by the end of 11th Plan period at a CAGR of 9.5%. The state-owned coal companies CIL and SCCL are projected to produce around 460 Mty and the balance of around 120 Mty will be from the captive mines. CIL plans to raise its coal output to 520 Mt by 2011-2012 from the present 380 Mt. Production from underground nines stands at 44 Mt, while opencast mines account for 336 Mt at present.

CIL is planning to usher in a new era in mining technology for its huge untapped coal reserves. CIL will introduce high wall mining in India and has also turned to global mining majors to raise production output. To begin with, CIL has identified 17 mines for high wall mining in South Eastern Coalfields. High wall mining is a form of surface mining where a continuous mining machine is driven using remote control into thin seams exposed by previous open cut operations. CIL plans to produce 20 Mt a year from high wall mining by 2011-12. In India, CIMFR has provided the state of art design for the first likely highwall mining from OC-II project, SCCL.

Mining and processing of coal are simplified immensely by use of surface miner. That result in higher system availability, lower operating costs and less effort for job planning, operation and maintenance. Surface miner technology was introduced in few projects of MCL/SECL in addition to inpit-crusher and shovel combination to win coal in few mines.

Apart from introducing new technology, CIL is also scouting for technology partners from China, US, UK and Australia to raise the output from its surface and underground mines, including the abandoned mines.

Due to non-availability of the duping land, the height of the dumps are going on increasing. It required geotechnical study for optimum slope design of these high dumps. CIMFR has been instrumental for the optimum design of 120m high dumps in and around many coal mines. We have conducted geotechnical study of overburden dumps to ensure the minimum land acquisition for the development of external dumps and to get the maximum height in case of internal dumps without compromising the safety and to accommodate the maximum overburden dump material.

Non-coal surface mining

India is having widely varying geo-mining conditions and some mines, which will be going to deeper depths, will have poor to adverse hydrogeological condition. Some of the old mines were designed on empirical basis and massive slope failures have occurred at very shallow depths. Some are having problem of high stripping ratios. Problems of increasing water pressure are becoming a feature and drainage of water by vertical pumps and by horizontal drainage is becoming essential. To get better data inputs, it is most essential to install sub-surface instruments to know water pressure likely to be operative during pit operations.

The slope failures and large movements, related to large and deep open pits of excavated depth up to 100-150 m and dumps of 30 to 60 m height on flat and inclined ground, have focussed the need to design them for short-term conditions and to conduct in depth geotechnical studies to prevent such slope and dump failures. The CIMFR is involved in more than 50 coal and non-coal opencast projects in different fields of open pit mining. The future operating depths of some of the mines designed by CIMFR are presented in Table 1.

TABLE 1: FUTURE OPERATING DEPTHS OF NON-COAL MINES

Region	Mineral	Designed depth (m)
Rajasthan	Rock phosphate	200
	Lead-zinc	372
Orissa	Chromite	150
Goa	Iron ore	150

The geotechnical studies conducted by CIMFR have been very useful for different mine managements to work at steeper slope angle which has saved a vast sum of money for them. The steep slope angle backed by detailed geotechnical studies had saved the degradation of invaluable Mother Earth. The least land area was used for the exploitation of the minerals and a number of valuable and rare flora and fauna could be kept in their natural environment.

To save on rock excavations, it is essential to carry out intensive monitoring. Investigations into the stability of high benches and small berms of the pit have become call of the day. As copper ore reserve is not high in the country, steepening of slope was attempted at Chandmari copper project to keep the cost of mining to a minimum. The designed overall slope angle was 60° to a depth of 148 m and bench height up to 20 m. This is the steepest slope angle designed and successfully executed opencast mine in the range of 150m depth. Malanjkhand copper mine has been designed for about 200m depth. Recently, Agucha lead zinc mine, being operated by HZL, has been designed for 372m depth. It would be deepest open pit in India in coming years. Slope monitoring is being done in a number of deep mines to detect instability in and around the operating mine for the safety of men and material working at deeper levels of the mine.

Environment and surface mining

The environment scenario toady is not as bad as it was earlier. There has been wind of changes in the attitude of some enlightened management to minimise adverse environmental impact through environment-friendly mining methods, improved technology, damage limiting practices, effective rehabilitation measures, integrated planning and a measure of social awareness and sensitivity. Enactment of legislation and its enforcement, monitoring by various agencies including local inhabitants, and external funding conditionality have significant effect in terms of better and sustainable mining practice helping to erase from the public mind the ill effects of surface mining.

Greening of overburden dumps has become an acceptable practice and, in most cases, this is achieved by trying to grow plants in small pits of sufficient depth filled with soil and nutrient materials.

One of the difficult tasks in plantation has been to vegetate the dump slopes successfully. In cases where the single stage of dumps are high (above 25 m or so) and the perimeter slopes are formed at the angle of repose of the waste material at about 37° the problem of erosion becomes critical for the survival of plants.

A novel approach which claims a measure of success is to build small walls of loose stone pieces (from the dump material itself) on the slope which serves the purpose of trapping the slope wash fines and provides a platform after a monsoon for the plants to be seeded and grown. This appears to be an economic and effective way for solving the vexed problem of slope vegetation without resloping of a dump to flatter angle of 24°. In some mines, supplying cement grade limestone, the waste rock dumps are suitably terraced, stepped and vegetated by sowing grass seeds to be followed by plantation.

The concern for protection of the environment has become very widespread in recent years, specially during the last decade. So far as environmental consequences of mining are concerned, the public has a poor image of the industry. The mining in Jharia and Raniganj coalfields has been accompanied by deforestation and general environmental degradation. The outcry against environmental damage due to mining have resulted in the stoppage of limestone mining in Dehradun-Mussoorie area and block of the bauxite mining project in Gandhamardam hills in Orissa. There have also been a lot of concerns due to the water pollution problem created by iron ore mining in the Singhbhum and Bailadilla area.

The use of mobile crusher technology with conveyors has its main advantage in the replacement of large truck fleets and the ancillary equipment and their maintenance costs. As a result this mining technology has less impact on the environment due to a reduction in use of oil based products (disel fuels, oils) and tyres coupled with substantial reduction in noise and dust generation. The effort at environment conservation is not limited to the spoil dumps only but has spread in all spheres of mining activity. Some mines have planned and effectively implemented the precept that "mining is only a temporary use for the land and it must return to a more permanent productive use". A case in point is that of a limestone mine located in the southern part of Saurashtra peninsula along the coast line.

With a purposeful mining thrust and prudent management available overburden of calcareous sand and silt, backfilling of mined-out area in segments, construction of roads and ramps, and creation of artificial lake of sweet water by impounding whatever amount of rainfall is available have been achieved, thereby preventing any mine discharge and consequent clogging of a nearby harbour. The mine took up a challenging task of vegetating along the neighbouring sea coast plagued by shifting sand dunes and blowing sands rendering the in-bye areas sterile and barren. With the success achieved in plantation arresting the moving sands resulting in a hospitable environment for growth of vegetation, the hitherto barren land has been transformed as a habitat for a variety of bird species both resident as well as migratory.

The in-land area farther from the coast, now rid of the intruding sand particles, have been regenerated as a fully cultivable land. Incidentally, the mining operation benefited due to containment of high noise level and also adverse effect on machinery due to the floating dust.

Another recent case of high performance is that of a bauxite mine in the Western Ghats. The mine has an ecological fragile setting with three water reservoirs within the buffer zone of 10 km radius and a proposed sanctuary in close proximity. Interpreted from mining viewpoint, it means no solid washouts beyond the mineralized area, no fugitive emission from the pit within acceptable limits, no drilling blasting, and restoration of the landscape. The high objective set forth by the mine was successfully achieved by a total environment-friendly approach. To start with the topsoil is scrapped and preserved, overburden and the ore excavated by ripping and hard boulder broken by hydraulic rock breakers, eliminating dumpers altogether. Additionally atomized water sprinkling at ripping site, overburden dumps and exposed faces reduces significantly the air-borne dust. The overburden dumps are surrounded by walls to reinforce slopes and channelise the water run-off to siltation tanks through garland drains to trap the suspended particles. The water is fed to a pond at the top of the plateau to serve the dual purpose as bio-indicator with the help of fish and duck culture of testing the water quality and also to recharge the water table, a common practice in the Western Ghats.

Riding piggyback on the growing environmental movements, elimination of drilling and blasting is on the agenda for any environmental action plan specially in the fragile or environment-sensitive locations. Ripping as an alternative has emerged in the forefront and a number of limestone and bauxite mines have successfully adopted the technology. Ripping has been adopted selectively in a captive limestone mine to meet partial production requirements. The same mine has also seen the advent of a surface miner, restricting the requirements of drilling and blasting. Surface miner is an eco-friendly technology and it has found quite a few applications in limestone mining as a protection to the environment.

Computerised opencast mine planning

With the increase of size of surface mines and various alternatives available in terms of type and size of excavating, transport and other machinery, the tasks of detailed planning

of such large surface mines are found to be tedious and time consuming not to mention the complexities involved, if performed manually. This is so because the process of mine planning, being an iterative method, involves a lot of computation work and handling a large number of data to generate and test different alternatives to arrive at the optimum one. However, the application of computer for mine planning can greatly minimise these difficulties provided that a suitable model is available which is easy to manipulate in a computer. Hence, computerised mine planning is making headway in the surface mining industry. Modular implemented its first mine management system, called "Dispatch", for haulage optimization in open pit mines. Since that time, this system has been placed worldwide. Initially just used for dispatching haul trucks, the system has evolved to provide complete, real-time and historical production data and maintenance data. It also allows connection to onboard PLCs (programmable logic controller) supplied by major equipment manufacturers for monitoring machine data and global positioning system (GPS). Computer software for mine modelling and design has been evolving into systems which are strong on interactive graphics, high quality visualization of surface and solids, and friendly user interfaces. Fortunately, the days of compiling a file full of numbers to make a programme run are long gone. Inexpensive desktop hardware can provide sophistically graphics and interactive CAD. The latest computer and software technology helps engineers and geologists accomplish mine design and production tasks quickly and efficiently.

Blasting in surface mining

The damage due to poor blasting has a significant influence upon stability of highwall slopes. Uncontrolled blasting results in rough uneven contours, over breaks, overhangs and extension of tension cracks in the slope. Poor blasting causes opening between various weak planes, which result in loss of resultant cohesion between them. It also results into shattering of the slope mass well behind the desired location and consequently allowing easier infiltration of surface water, which leads to unfavourable groundwater pressures and related problems.

A number of problems exist including ground vibration, noise, fly rock and back breaks in mines which are operated in the proximity to buildings and other surface structures.

Innovations in blast-initiation systems coupled with sequential blasting machine, sophisticated seismographs for monitoring of blasting vibrations and controlled blasting techniques have helped blaster to fire large blast with better fragmentation and reduced vibration effects.

Future of mining industry

Mining and mineral industry in India is currently trying to attune itself with the new industrial order that is emerging in the country. In the mining environ, there will be increasing emphasis on opencast mining to meet the increasing demand for all the minerals. A number of large opencast coal mining projects are currently under various stages of implementation, which suggests that opencast coal mines designed to produce up to 14 million tonne per year would come into operation. Mines operating at depths 300 to 400 m with stripping ratios of 4 to 5 would require total handling of around 40 million tonne of material per annum with the help of 170 t dumpers and 20 m^3 shovels.

Formulation, planning, designing, construction and operation of such gigantic units are likely to pose challenge hitherto unknown on account of attendant complexities. Newer machines and technologies are likely to emerge to the fore resulting in adoption of computerisation and automation in greater measures.

The Government of India by its recent modification of MMRD Act paved the way for foreign investment in mineral sectors. The new economic policy of the Government coupled with the desire of the Government of the massive development of the mineral sector with the aid of the foreign investors is likely to yield significant benefits in near future. It is, however, apparent that primary target for the multinationals in the initial phase will be restricted to coal, diamond bearing areas and large deposits of low grade gold ore at shallow depth. For copper production, India used to be solely in the hands of state-run Hindustan Copper Limited. Sterlite is the first of several private sector companies, which is going for copper production since the government deregulated the industry.

Conclusions

Today, Indian mining industry is at its crossroads. Increasing competitive pressures being faced by the Indian mining industry through globalisation of the economy presents a big challenge on how to improve the current level of production and productivity in mines profitably. To ensure high performance, there is scope for introduction of mechanised surface mining system with large size equipment and switching over from diesel powered equipment, use of mobile or semi-mobile crushers with high capacity conveyor, introduction of total mine management system with truck dispatcher system (TDS).

Improvement in equipment utilization is an economic necessity in Indian mines. Technical appraisal of equipment before selection, quality assurance and preventive maintenance with adequate spares should receive priority attention for good results. By employing state-of-the-art blasting technology, opportunities to achieve substantial improvements in down-stream costs exist. Use of modern blasting technology tools should be encouraged to reduce overall mining costs. Increased input of 'behavioural sciences' into mine management courses and established training programmers will enormously reduce accident related

losses. Interaction with scientific institution will help to resolve many technological issues and thereby improve productivity.

We must create necessary environment and management responses to make changes that will improve productivity with emerging technology. Scheme of "reward and punishment" should be introduced systematically to improve mine productivity. However, the problem associated with opencast mining is the environmental degradation, as much as effective measure have to be taken from the very conceptual stage of the projects and the three-circle approach (Technology + Economics + Environment) should be followed to make opencast mining eco-friendly. Surface coal mining segment of the Indian coal industry has been the sheet anchor of industry's production growth meeting the burgeoning energy demand of the nation. In the face of escalating demand for coal, there will be increasing thrust on the surface mining sector to bridge the supply/demand gap. There are compelling reasons also for increasing the competitiveness of the coal sector by addressing the key issues of productivity through recourse to new technology and by reengineering the processes. Surface coal mining will continue to be the centre piece of Indian coal sector and transforming the bottomline of the coal industry will be possible only through productivity enhancement of this sector.

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