Government of India
Ministry of Labour & Employment
Directorate General of Mines Safety

DGMS (Tech.) (S&T) Circular No. 02 Dhanbad, Dated 06.07.2010

To

All Owners, Agents and Mangers of Mines

Subject: Design, Control and Monitoring of Pit and Dump Slopes in Opencast Mines

Sir,

1.0 INTRODUCTION:

In India, fast increase in output of various minerals can be largely attributed to rapid increase in opencast mining activities and intensified mechanization. This has resulted in the opencast mines going deeper day by day with the maximum stripping ratio being planned currently looking upto 1:15, at a depth of about 500 m. As a direct consequence, the amount of waste mining and dumping will also be commensurately very high thereby increasing the risks of highwall, slope and dump failures tremendously. With more and more stringent environmental damage control regimes and non-availability of alternative lands for aforestation purposes, the risks assume very complex proportions with the deep excavations and growing dumpyards altering the complex stress concentration levels. Under such situations with most production areas concentrated close to the excavation floor, there is a constant danger to the men and machinery deployed thereat with a potential to cause catastrophic loss of life and property.

An analysis of the accidents in opencast mines revealed that slope failure and dump failures have started assuming an upwards trend in the recent times. A few of the recent fatal accidents/dangerous occurrences in opencast mines involving slope and dump failures were as follows.

a) In Kawadi Opencast coal mine of M/s Western Coalfields Limited on 24/06/2000 in which ten persons including the blasting overman and sirdar were trapped and killed due to slope failure of 31 m high over burden bench.

b) in Tollem Iron Ore Mine M/s Kunda R. Gharse in Goa on 09/12/2006 in which six persons were trapped and killed under the debris due to slope failure of 30 to 46m high Dump and benches in the mine.

c) in Jayant Opencast Project of M/s Northern Coalfields Limited on 17/12/2008 in which a portion of the dragline dump measuring 135m (length) x 70m (height along the side of the slope) x 6 to 19 m (height across the slope) failed suddenly and trapped five persons to death and buried a shovel at its bottom.

d) In Sasti Opencast Coal mine of M/s Western Coalfields Limited on 04/06/2009 wherein a dragline overburden dump of 73m height failed and slided down the pit resulting in deaths of two persons and burial of two excavators.

e) In Hamsa Minerals and Export Granite mine on 25/2/2010 where a mass of Granite stone measuring about 30m long X 35-45m height X 10m thickness slid along a known inclined joint plane and fell from a height varying between 10 to 55m on 18 persons working at the pit floor them burying and inflicting fatal injuries to 14 persons with serious bodily injuries to another.

f) In a private soapstone mine, a portion of the almost vertical 17 m high bench side with several undercuts slid suddenly, trapping and fatally injuring 3 persons working at the bottom. This was immediately followed by a subsequent failure from the same area measuring about 8m long X 7m high X 1.5m to 2.0 m thick which trapped another five persons who were engaged in the rescue operations.

g) In another coal mine, a total volume of around 1,30,000 m^3 of waste material slid from a height of 10 m to 12m to the bench floor, without involving any casualty.

h) A deep seated circular failure of an overburden dump about 62m high, made on the foundation of 10-15m thick soil, caused severe upheaval to an adjacent arterial road and damage to a 400 KV overhead line in a coal mine. The road got totally blocked and power supply got disrupted.

The analysis also converged on one common but a major factor causing the accidents that of the lack of scientific design and monitoring of the pit and the dump slopes in mines.

There are several ways to reduce the chances of surface ground control failures as given below.

(a) Safe geotechnical designs,
(b) Secondary supports or fall catchment arrangements and
(c) Monitoring devices for advance warning of impending failures.

Safe geotechnical design is with a single focused objective that of ensuring adequate stability against any failure while working, involving the complete study of local geologic formations/structures, rock mass properties, hydrologic conditions and the rainfall pattern about the openpit. While a flatter slope always means better stability, it also involves permanent locking up of huge quantities of mineral reserves. On the contrary, steeper slope greatly increases the potential of failures. Therefore, a scientific balance has to be constantly established between the two situations catering to the expected life of the benches.

While it is very important to have good geotechnical designs of dumps and slopes, effective monitoring and examination of slopes for failure warning signs is the most important means of protecting exposed mine workers. Even, very carefully designed slopes may experience failure from unknown geologic structures, unexpected weathers or seismic shock etc. The problem of such failures are getting compounded manifold due to non-availability of land for dumps leading to increased height of the existing dumps, poor drainage systems, proximity to inhabited areas, non-separation of top-soil during excavation, etc.

2.0 Monitoring of Side and Slopes in Opencast Workings:

Conventional monitoring methods depend on regular surveying of the sides and slopes of the benches and dumps using the most modern survey instruments and associated software. Additional instruments can be used as part of a comprehensive system to register subsurface rock mass displacement, groundwater parameters, and blast vibration levels. Aside from visual inspection, these methods provide displacement information only for a single site, or at best, at discrete number of sites. If the monitored sites are too widely separated or if displacement occurs between sites, early indications of an impending slope failure might go unnoticed. In addition, these monitoring tools are difficult to install at many quarries and surface coal mines where steep highwalls and lack of benches limit access to areas above the working floor which is very common in dragline dumping in coal mining. With the constantly shifting mining front and the need for regular monitoring increasing steadily, relocating monitoring devices is not only costly and time consuming, but can also be dangerous on unstable slopes. Point-by-point monitoring of every potential failure block in a mine or dump slope is not practical. In some countries, scanning laser rangefinders have been used wherein ground displacements were detected by comparing successive scans but processing requirements and scan rates have so far made repeat pass intervals too great for effective and timely slope monitoring. In addition, the range and accuracy of these systems are impaired by differences in the reflectivity of the rock, the angle of the rock face, weather, and other factors.

However, radar technology - used widely in a variety of fields for several decades, has found its utility of recent in monitoring ground movements in mining applications. This technology sports distinct advantages over conventional methods in its ability to cover large areas on the surface for true two-dimensional monitoring day and night in almost any weather, and atmospheric dust and/or haze have little effect. Radar's active transmit/receive mode of operation also provides an advantage over passive optical methods that depend on solar or other illumination/reflection etc. The present day advanced computing techniques have provided the low-cost processing power needed for complex ground movement computations. Further, the widespread adoption of modern wireless communication devices has resulted in practical integrated circuits for microwave frequencies that can be used in task-specific radar applications.

Slope Stability Radar (SSR), developed on the above radar technology, is now being widely used in several countries to provide real time monitoring and advance warning signals before any slope or dump failure in opencast mines. The SSR system can detect and alert movements of a wall with sub-millimeter precision, with continuity and broad area coverage. This monitoring occurs without the need for mounted reflectors or equipment on the wall or slope and the radar waves adequately penetrate through rain, dust and smoke, 24 hours a day. The SSR system produces data for interpretation usually within minutes. The radar is moved around the mine in a repeatable manner to compare movements at each site over an extended time, and determine problematic areas. Cyclic monitoring off the focus area in this manner is often used to identify new places where impending signs of developing failure patches are observed. The latest instruments have the radar technology suitably integrated with a real time visual imaging system for continuously scanning the problem area to identify the potential areas of failure and visualize any impending ground movement/failure, by comparing the repeated measurements against the first scan. Such systems can also have suitable audio-visual warning systems incorporated for activation at any pre-set value being breached due to ground movements. Alternatively, Synthetic Aperture Radars (SAR), a type of ground-mapping radar that was originally designed to be used from aircraft and satellites, may be used to generate high quality digital elevation maps and to detect disturbances of earth's surface.

All these point to the fact that, strong, reliable and person independent monitoring systems need to be introduced at Indian opencast mines on an urgent basis.

3.0 Application of Slope Stability Radar in Monitoring of Slope & Dumps in Opencast Mines:

The SSR have been successfully used in some countries with highly variable geotechnical conditions including massive hard rock, intensely fractured, foliated rocks, weathered rock, coal strata and waste dumps of variable characteristics. Several case studies of the SSR providing improved operational risk management by characterising the slope instability, and providing sufficient warning time prior to failure, have been reported all over the world during last five to eight years.

3.1 <u>Experiences in Coal Mines</u>

(i) The Mount Owen Coal Mine of M/s. XSTRATA Coal in Hunter Valley, Australia is one of the deepest opencast coal mines in Australia with depths in excess of 270 m and has extreme and unusual geological conditions. SSR installed in the mine indicated warning of huge failure (20 million m^3) four hours before its occurrence in January 2005 and saved valuable life and properties.

(ii) In Drayton and Leigh Creek Mine in Australia where SSRs were deployed, the advance warnings of impending failure of the slope were given 3 hours prior to the occurrences and resulted into safety of persons and the machinery.

3.2 <u>Experiences in Metalliferous Mines</u>

(i) Mount Polley Copper Mine of M/s Imperial Metals Corporation in British Columbia, Kimberly Diamond mine of M/s De Beers and Sandsloot Open Pit Platinum Mine of Mis. Anglo Platinum in South Africa and many other mines have reported successful deployment of SSR and its timely detection and warning system that has saved many precious lives and property.

(ii) Rampura and Aghucha Zinc Mine of M/s Hindustan Zinc Limited in Rajasthan, India is the only mine in India where SSR is being used to monitor its opencast workings to give pre-warn against any such slope failures.

4.0 Conclusion and Recommendation:

In view of the scenario explained above, it is essential to take following steps immediately:

(i) Design mine and the pit as well as dump slope scientifically taking into consideration of geotechnical parameters of rock and the dumps including hydro geologic and weather conditions to ensure stable Pit and Dump slope profile not only during mining but also thereafter; and

(ii) Deploy Slope Stability Radar (SSR) with integrated visual imaging system or any similar such technology giving a real time monitoring of displacements of strata or dumps well in advance of any failure and providing mine management sufficient time to safely withdraw men and machinery from such prone areas. Such systems would not only increase safety but also the productivity and efficiency of opencast operations.

In view of the seriousness of the implications of ground movements in openpit excavations, all mining companies having openpit excavations are urged to immediately initiate a time bound concrete action plan on the above matters.

(S. J. Sibal)
Director General of Mines Safety