ASSESSMENT OF SEISMIC RISK AT KONKOLA MINE – No 1 SHAFT

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Abstract

Seismicity at Konkola Mine No 1 Shaft started suddenly in January 1995. Initially, only the Southern side of the Mine was affected covering a stretch from 380mS to 550mS.

Seismic activity at Konkola Mine occurs suddenly, with virtually no warning signs. Two distinct seismically active zones have been delineated, 3150L 300mS-S and 3150L 155mN-N. The mining methods employed in these areas are Sublevel Open Stoping with Mechanised Draw points and Sill Pillar Recovery "SPR" respectively. A 5-geophone seismic monitoring system has been installed at the shaft.

This paper discusses the nature of seismicity at No. 1 Shaft, damage caused by seismicity and its relationship to stoping. It also discusses challenges to predict/prevent injury and damage in order to mitigate effects of seismic events and also lessons learnt from previous seismic activity with a view of using the past mining practices/experiences to manage seismicity.

The paper concludes that it is important to monitor seismicity in a mine in order to check the effectiveness of designs, identify other possible hazardous areas and also learn from history and apply the knowledge gained to manage seismicity.

SEISMICITY AT KONKOLA MINE

Ever since Konkola Mine No. 1 Shaft started experiencing seismicity in January 1995, quantitative and qualitative seismological data has been recorded.

The first monitoring system was installed in November 1995. This seismic monitoring system could not give the location of events, but could determine the local Magnitude and the Energy released. With time the system could not give qualitative data and was replaced with a real time modern ISS micro-seismic system, which was commissioned on 1st February 2002. The new monitoring system consists of five (5) geophones and each geophone is installed in a 10m deep vertical borehole located at different underground elevations. The new seismic monitoring system is able to locate events and also gives quantitative seismology information. Based on this seismic data, as shown in Table1, it has been concluded that Konkola Mine No 1 Shaft experiences seismic events with relatively small local magnitude, which result in shakedown events or face bursts. This implies that seismicity at No 1 shaft is not related to major pillar failures.

Year / Magnitude	'95	'96	'97	'98	'99	2000	2001	2002	2003	June 2004
-0.6 – 0	0	0	0	0	1	1	17	1215	39	43
0 – 0.9	0	0	0	1	6	6	8	393	132	79
1.0 – 1.9	1	3	1	2	0	0	0	30	1	7
2.0 – 2.9	0	0	0	0	0	0	0	2	0	2
> 3.0	0	0	0	0	0	0	0	0	0	0

Table 1 Showing seismic events recorded. The Seismic Monitoring System was out of order from April 2003 to November 2003.

SEISMIC DAMAGE AT KONKOLA

Trends of areas affected by seismicity are changing all the time. Initially, the Ore body and Footwall/Extraction Drives were more affected than Crosscuts. Sometimes Crosscuts are more severely and more frequently damaged than Drives.

In drives, the rock burst type of ground damage is observed to come mostly from the top eastern corner, as indicated in figure 1 and 2, and midway between the roof and the floor of the crosscuts. The depth of damage is up to 4m. Very little damage, if any, is experienced in the western part of the roof and in the western sidewalls. Sometimes, stress induced fracturing of ground is observed in the eastern sidewall.

A bedding plane usually bounds the surface in the top part of the failure zone. In the eastern most corner of the failure zone, the surface is frequently conchoidal (rough) and curved; refer to figure 1 and 2. The bottom part of the rock failure zone is also usually a conchoidal curved surface.

Figure 1. Picture showing ground damage after the occurrence of a seismic event

Overall, the shape seen in drives damaged by seismic events is that of a "dog-ear", as can be seen in figures 1 and 2. The same shape is seen in most drives in other high stress areas that do not experience seismic events. The shape suggests rock failure in compression by a principal stress in a direction sub-perpendicular to the failure zone that is from the top western side and dipping towards the east. It has been observed that areas that experience rockbursts always undergo high stress type sloughing of rocks for some time before a rockburst occurs. This means that seismic events occur only in high stress areas.

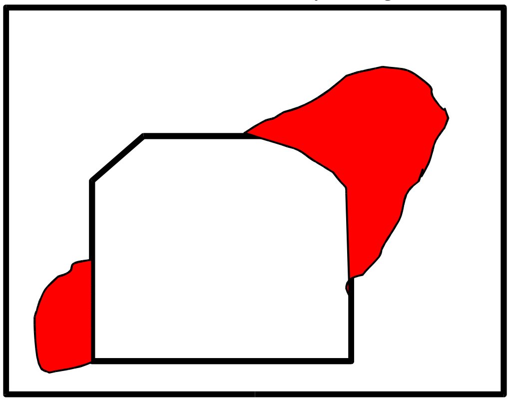


Figure 2. Shows a " dog-ear" shape damaged zone after a rock burst

When there is a lower stress loading the ground falls in thin curved slices, like onionskins. The sloughing of ground from the failure zone is more if there is no rock bolt support although it has been observed that even where support is installed the rocks tend to fragment and fall around the roofbolts resulting in roofbolts protruding after sometime.

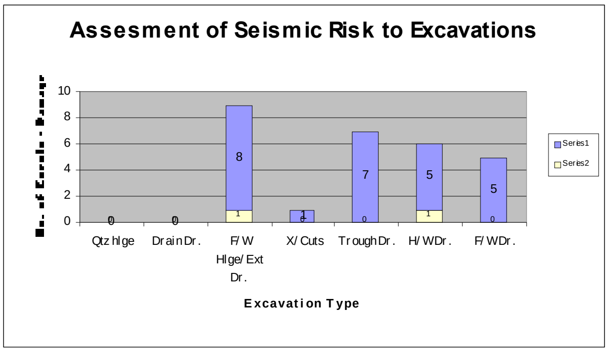
It has not been established that during seismic events there is more ground falling at junctions between drives and crosscuts than elsewhere. Rockfalls from seismic events tend to be largest at the point nearest to the highest concentration of stress irrespective of the presence of a junction.

Figure 3 Plan showing seismic damage in the Trough Drive located in the Ore Shale. Virtually no damage in FW Drive

Generally, the potency of ground damage from high stress conditions and seismic events reduces the farther away the excavation is from the Ore Shale in the footwall, as observed in figure 3. As a result, very few seismic event ground falls have been experienced in excavations located within the Argillaceous Sandstone rock mass and none at all have occurred in the Footwall Quartzite rock type (refer to figures 3 and 4).

Figure 4. Comparison of seismic effects on excavations in relation to the proximity of the excavation to the ore body

Ground falls after seismic events are usually 0.5m - 2.0m above the original roof surface and do normally fill up the excavations. Areas supported with 2.0m/1.5m long 10 tonne grouted roofbolts tend to show less damage than



unsupported spaces. However during severe seismic events, roofbolts have been noted to snap and pull out. Usually, rock bursts cause rocks to break around the roofbolts leaving them protruding. Wiremesh support has been observed to have been ripped apart during seismic events, like in the rock burst that occurred in the 2900 level 570mS Footwall Haulage on 02 June 2000 (figure 5).

Figure 5. Picture showing ripped diamond mesh and protruding roof bolts after a seismic event

Fragmentation tends to be fine when a rock burst has occurred, with most pieces being less than 0.5m in the largest dimension. However, shake-out type of rock falls due to seismic event vibrations tend to be very large pieces, with up to 2m width and height, being observed to fall out.

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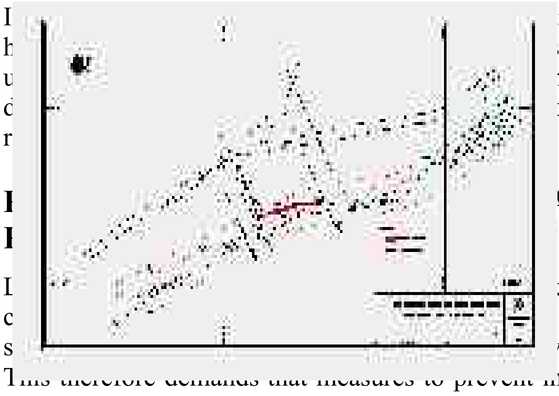

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I ... ces the c ... events, s ... warning. This therefore demands that measures to prevent injury to personnel and damage to machinery/equipment are put in place. In order to manage and mitigate the effects of seismicity, Konkola mine has learnt from previous occurrences and has instituted measures with regard to rock mass management strategy. This therefore, requires that adequate understanding of the geotechnical environment be in place in order to offer solutions and put measures to manage seismicity.

INFORMATION FROM PREVIOUS EVENTS

- Previous seismic occurrences indicate that seismicity at Konkola Mine – No 1 shaft is geographically confined to two distinct areas of the Mine. These are the 3150 level 300mS-S and 3150 level 155mN-N retreats, refer to figure 6. Mining methods employed in these areas are sublevel open stoping and sill pillar recovery “SPR” respectively. These two areas have common ground condition characteristics that are strong rock mass with uni-axial compressive strength “UCS” of 150 to 250MPa with Rock Mass Rating of 70-80 and stress levels exceed the rock strength. The stope Hydraulic Radius ranges between 7 and 10m. Further, the weak base “unit A” of the ore shale, which is, supposed to act, as a stress relief valve is absent (see figure 7). The strong and consolidated unit “A” present in the seismic prone areas, allows the stresses to be transmitted from the hangingwall to the footwall through ore pillars and remnants.

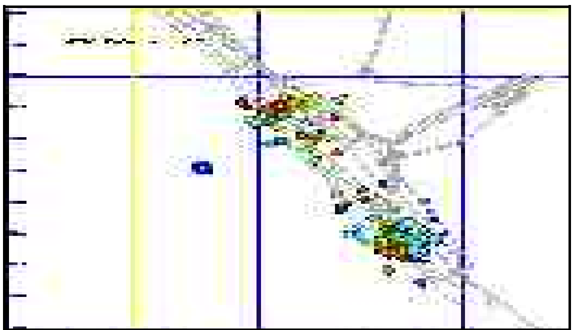


Figure 6. Plan showing seismic events in two areas of No. 1 Shaft affected by seismicity (3150L 155mN-N & 300mS-S)

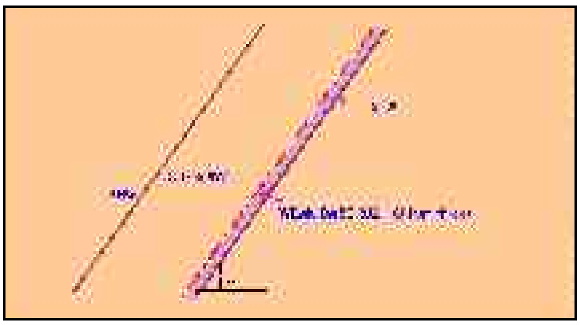
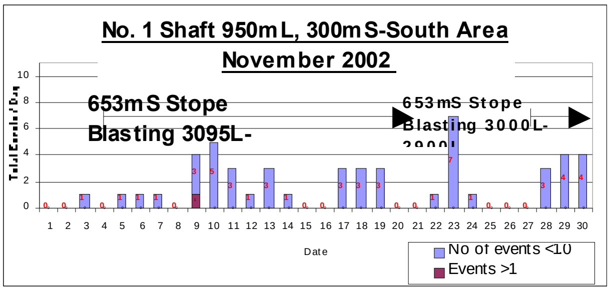


Figure 7. Weak base “unit A” of the ore shale is absent in the seismically active areas of Konkola Mine – No 1 Shaft

- The occurrence of seismic events does not appear to follow a time pattern, the events occur randomly in time. Previously, it was observed that seismic events could not happen during the development phase of tunnels, but in the recent past events have occurred during the development stage of tunnels. To a certain extent, seismic activity takes place some time after mining of the excavations has been done. This means that seismicity at Konkola Mine is more related to stoping operations than to excavation development activities.

Figure 8. Shows an increase in seismic activity during stoping operations, as stope ring blasting approaches the crown pillar, increase in seismicity is noted due to increased stress concentrations in the pillar.

- It has also been noted that seismic events seem to frequently occur close to stoping abutments both on



dip and along strike. Underground observations show that high stress sloughing and seismic event damage are normally more severe close to a stoping abutment than farther away. Although in general, ground damage intensity reduces in direct proportion to the distance the excavation is from the stoping abutment, there have been cases where ground damage has occurred at a position some distance away from the abutment.

- Current mining practice in seismic prone areas reveals that support is installed late thus, allowing smaller magnitude events to weaken the rock mass leading to shakedown events. Stope face configuration during ore extraction also leads to high stress concentrations in crown pillars, as observed in figure 8.

Seismic Management Strategy

Some measures have been put in place in order to mitigate the effects of seismicity. Some of the elements that have been critically looked at in areas prone to seismic damage with regard to the Rock Mass Management Strategy include:

Strategy: - Extensive line/damage mapping and rock mass classification have been carried out in order to identify hazardous areas. With detailed analysis of the mining methods employed in these seismically prone areas, it has been recommended that sublevel open stoping and sill pillar recovery “SPR” should continue, however Cut and Fill mining method is being considered as an option.

Layout: -The layout for 3150 level 300mS-S area has been reviewed, resulting in the eliminating of the Hangingwall drives which experience seismic related damage. This entails that all stope-drilling operations are conducted from safer footwall excavations.

Schedule: - Stope extraction has been reviewed in order to minimise stress concentrations. Further, stope spans have been changed from 20m to 12m, meanwhile pillar sizes have been maintained at 8m.
Support: - Hazardous areas, which have been identified to be prone to seismic damage are supported well in advance. The primary support density of roofbolts has been increased by changing the spacing to 0.8m rather than 1.0m. In order to increase energy absorption of the primary support systems installed, lacing and other retainers such as wiremesh and tendon straps are additionally installed. No passive support of timber setts is installed.

Conclusion

Seismic activity is continuously monitored at Konkola Mine – No 1 shaft in order to check the effectiveness of Geotechnical designs, and regular seismic monitoring also assists in the back analysis of the performance of support systems. Further, quantitative seismological data recorded is used for scrutiny in planning meetings by Geotechnical Engineers to identify other possible hazardous areas. The checklist used to provisionally assess hazards is shown in Appendix 1.

With reference to the case study at Konkola Mine – No 1 Shaft on the assessment of seismic risk, it is concluded that we can learn from our past experiences and use these challenges for future designs and management of seismicity. Lessons learnt from history are therefore, being applied in the management of seismic related effects, for instance the mine experienced the last seismic related injury on 15th October 2001, 34 months to date no seismic injury has been experienced despite continued seismic activity. This therefore, entails that we can learn from history and apply the lessons learnt to mitigate the effects of seismicity, as is the case with Konkola Copper Mine – No 1 Shaft.

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Appendix 1

SEISMIC HAZARD CHECKLIST

	Score	
	Yes	No
1. Geotechnical Plan available – Logging - Mapping	0	5
2. Hazards are present – "A" Zone	0	5
- Weak ground (other)	3	0
- Faulting or Scaling	3	0
- Jointing and Bedding	3	0
- Abutment within 20m	5	0
- Pillars not wrecked	5	0
3. Excavations are located away from hazards		
- Footwall drives	0	3
- Crosscuts	0	3
- Ore body drives	0	3
- Raises and traveling ways	0	3

4. Excavations are mined according to standard - Footwall drives - Crosscuts - Ore body drives - Raises and traveling ways	 0 0 0 0	 3 3 3 3
5. Support is installed according to standard - Footwall drives - Crosscuts - Ore body drives - Raises and traveling ways	 0 0 0 0	 5 5 5 5
6. Seismic activity has occurred in this area	5	0
7. Seismic monitoring is in place	0	3

HAZARD RATING

		Action
LOW	0 - 19	Continue observation and monitoring
MODERATE	20 - 39	Review support installation
HIGH	50 - 86	Review sequence, support design