Elements of Seismic Hazard in Mines

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Understanding Seismic Hazard in Mines

1. Seismic Source: Magnitude, Energy, Potency, Apparent Stress and Source Displacement Patterns and Source Mechanisms.
2. Entropy: Order, Disorder and Stability – Implications for Mine Layouts.
3. Hazard Factors in Mines – by Mother Nature and by Father Miner.
4. What Seismic Monitoring Can and Can Not Do. Can we Predict? Prediction vs Forecast. What we Can and Can Not Forecast.
5. Uncertainty, Seismic Hazard and Risk, Risk Management Cost.
6. Can we Expect the Unexpected? Probability of a Jump.
7. Size Distribution Hazard. The Maximum Possible Event vs the Next Record Breaking Event.
8. Time Distribution Hazard. Intermediate vs Short Term Hazard – Homogeneous vs Transient and Step Loading.
9. Ground Motion Hazard.
    (a) Peak Ground Velocity (PGV), Elastic and Inelastic Strains in Rock, Ejection Velocities and Perceptibility of Ground Motion.
    (b) Cumulative Absolute Displacement, CAD and Cumulative Absolute Inelastic Displacement, CAID.
10. Simple Ground Motion Prediction Equation and its Utility.
11. Seismic Fragility Curves, Support and Damage Potential
12. Seismic Alerts and Re-entry.
    (a) Polygon-based Methods.
    (b) Influence-based Polygon-less Ground Motion Alert – GMAP.

Seismic Hazard Management Plan: Seismic Monitoring

1. Shortcomings of the SHMP for Seismic monitoring.
2. Stating the Expected Seismic Rock Mass Response to Mining.
3. Objectives of Seismic Monitoring in Mines: Rescue, Prevention, Hazard Assessment, Alerts, Back Analysis.
4. Monitoring Technology and Skill Required to Achieve These Objectives.
5. Action Plan: Tasks to do Daily, Weekly, Monthly and Yearly to Achieve These Objectives.
6. TARPs: Set of Actions in Response to a Deviation From the Expected.

Introduction to Seismic Hazard Management Plan (SHMP) Seismic Monitoring

As mining goes deeper and the footprint and the extraction ratio of the ore bodies increase, more underground mines will denote seismic as being the principal hazard, i.e. hazard that has a reasonable potential to result in multiple deaths in a single incident or a series of recurring incidents. The process starts, or should start, before mining commences with deriving the expected seismic rock mass response to mining, which constitutes the reference seismic hazard. In such a case there is no seismic system, therefore no data, so the expected hazard depends on the expert opinion taking into account the nature of ore body, its geological setting, the planned mine layout, the results of numerical modelling of the expected stresses and strains, and by taking into account the experience of other mines in similar conditions.
However, in many cases at the inception mines did not expect to experience seismic problems, therefore, frequently the first hazard assessment is done at a later stage when either underground workers reported “rock noises” or after the first incident of damage caused by the perceived seismic event. Most seismically active mines monitor seismic rock mass response to mining and in these cases seismic hazard should be assessed quantitatively in terms of probabilities of exceedance of certain magnitudes and the resulting ground motion.

The seismic monitoring part of a good SHMP should be logical, consistent and quantitative. All criteria should be defined to facilitate quantification and each routine task and action timed and costed. The plan should also provide a framework to ensure compliance with the local health and safety regulations. At the same time it should be realistic, i.e. should not be overly ambitious to make sure that the mine will be able to deliver on its own commitment. It should be reviewed every 6 months, or every time the seismic rock mass response to mining delivers the “unexpected”. In preparation it is useful to follow a four step process accepted by the industry. (1)Identify the type and the nature of seismic related hazards, e.g. slip on geological structures, bursting of pillars, gas and rock outburst from a face in coal mines. (2) Assess the risk, i.e. the expected consequences, associated with each type of

hazard as measured by the magnitude and the probability or frequency of occurrence, and then score it in the company accepted risk matrix.
(3) Specify measures to be taken to manage seismic hazard and minimise the risk, e.g. changes to mine layout and/or the sequence of mining, rate of mining, introduction or changes to regional or local support, introduction of preconditioning, etc. (4) Reassess seismic hazard and review control measures.

The seismic part of the SHMP should include the following elements.

1. The specific objectives of seismic monitoring for the mine.
2. What the mine needs to have to achieve the stated objectives, in terms of seismic monitoring technology and people and skill involved.
3. What the mine needs to do to achieve the stated objectives, i.e. a list of tasks the mine needs to do daily, weekly, monthly and yearly to achieve the stated objectives.

Having the seismic part of the SHMP one can prepare a Seismic Trigger Action Response Plan that defines conditions, called here triggers, that need to be continuously checked for and the respective actions to follow when those conditions occur. Actions are triggered when **Seismic Alerts** show that seismic behaviour deviates from the expected. The SHMP and TARPs should be reviewed twice a year or every time seismic rock mass response to mining exceeds expectations in a significant way

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