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Destress Blasting – From Theory to Practice

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Abstract - One of the most common methods that are practiced today for controlling violent rock failures in underground mines is destress blasting. One aspect of this method involves drilling and blasting areas that are stiff and highly stressed such as pillars, mining fronts and shaft sinking floors, to help dissipate high stress and energy accumulation, thus rendering a safer mining environment. Another aspect of the method relies on large scale blasting of one or more slots or panels near the active mining area to create a stress shadow around it and help reduce the stress and energy concentration. While the merits of the destress blasting method are conceptually well appreciated by many mines, its efficient implementation in the field has been hampered by the diversity of available information, the scarcity of well-documented destressing programs, as well as the absence of a dedicated design/analysis method. This has made the destress blasting method more like an art than an engineering science. This paper reviews the background theory, benefits, constitutive modelling, and practice of destress blasting. Current research on the evaluation of the destress blasting efficiency is discussed, and future research directions are highlighted.

Keywords: Mine Safety, Rockburst, Destress Blasting, Rock Mechanics, Ground Control, Underground Mining.

1. Introduction

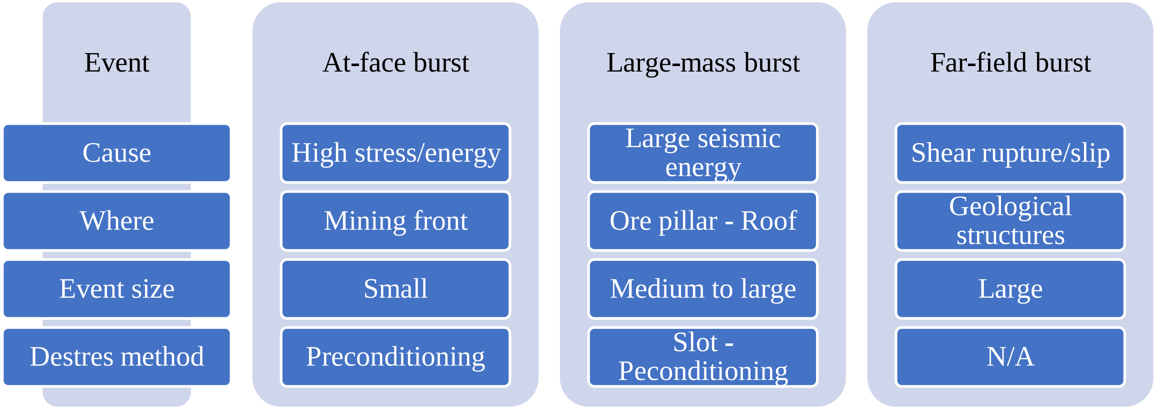
Destress blasting is a commonly practiced ground control technique in many underground mines. It is considered a mine safety tool because it is used to control seismic events that could lead to rockburst. It is practiced in both metal and coal mines albeit in different ways. This paper focuses on the application of destress blasting in metal mines for rockburst control. The strategies adopted to reduce stress and stored energy in the target rockmass are reviewed. One approach involves drilling and blasting the target areas, which are usually stiff, brittle, and highly stressed. Examples of such areas are crown pillars in cut-and-fill mining, mining fronts in face advance, and shaft sinking floors. The goal is to help dissipate high stress and energy accumulation in the target rock mass, thus rendering a safer mining environment. Another approach relies on large scale blasting of a nearby slot or a panel, but not in the active mining area. The goal is to create a stress shadow around it and help reduce the stress and energy concentration to enable mining production. The paper will then review the numerical modelling approaches that are reported in the literature to help better understand the benefits of destress blasting. Finally, the evaluation of the efficiency of destress blasting application using field instrumentation is discussed. Future research directions are also highlighted.

2. Classification of Rockburst Phenomena and Destressing Strategies

Numerous classifications of rockburst phenomena can be found in the literature e.g. Ortlepp and Stacey (1994). However, they can be grouped into three broad categories, namely at-face bursts, large-mass bursts and far-field bursts. At-face bursts are generally attributed to sudden release of high stress and energy at the mining face. Such bursts are relatively small in their seismic moment magnitude but are violent enough to cause local damage and injury. The use of light density blasting in drill holes ahead of the mining front is a form of destress blasting that is known as preconditioning (Karowski et al., 1979). At-face events can be a strainburst, buckling of boundary layers, face crush or any other form that is associated with the presence of high concentration of mining-induced stress and energy in strong, brittle and massive rock near or the boundary of the mine opening.

Large-mass events on the other hand encompass the rockburst of a large volume of the rock mass representing an ore pillar (a group of mining stopes) in a metal mine or the sudden rupture roof a longwall mine or a room-and-pillar mine during in retreat. Such events are characterized by a large and sudden release of seismic energy. To alleviate large pillar bursts, one or more slots or panels are created near the ore pillar by production-like blasting in the hope of creating a stress shadow around the ore pillar to enable safer stope extraction (Andrieux et al., 2003). In the case of large mine roofs, long holes are drilled into the roof off the roadways and light-density blasting is applied to induce roof breakage behind the coal face as the longwall advances (Konicek et al., 2011). The process is repeatable.

The third broad category of rockburst phenomena is far-field events. These are caused by either violent shear rupture of stiff geological structures such as dykes or sudden shear slip along a structural feature like a fault. Far-field event do not usually occur at the mining face; however, the seismic wave triggered by a far-field event can easily propagate and reach the free mining face causing far more damage to the mine opening than at-face events. While the causes and mechanisms of fault-slip bursts have been well investigated in recent years (e.g. Sainoki and Mitri, 2014, 2015, 2016), to date, there has not been a clear recipe for the alleviation of far-field seismic events attributed to fault-slip and shear rupture of geological structures. More research focus is still needed in this area. Figure 1 presents a summary of the rockburst phenomena and possible destressing strategies.



Event	At-face burst	Large-mass burst	Far-field burst
Cause	High stress/energy	Large seismic energy	Shear rupture/slip
Where	Mining front	Ore pillar - Roof	Geological structures
Event size	Small	Medium to large	Large
Destres method	Preconditioning	Slot - Peconditioning	N/A

Fig. 1: Broad classification of rockbursts and possible destressing strategies.

3. Destress Blasting Applications

The method of rock preconditioning is frequently used in deep mine developments driven in high stress conditions such as haulage drifts and ramps. As illustrated in Figure 2, preconditioning is employed every time the mining face is advanced. The preconditioning pattern consists of four corner drill holes that are fanned outward from the longitudinal drift axis by 45°, with the top two corner holes directed upwards by 30° while the bottom two holes are kept horizontal or parallel to the floor. In addition, two holes are driven in the middle of the face in the direction of face advance. All holes are drilled to a length of twice the length of the blast round or face advance. The holes are loaded only at the toe to ensure that the blast is light enough not to cause damage or overbreak of the mine opening, but strong enough to create or extend fractures to reduce the stress around the opening. In practice, variations of this method are implemented. The hole length, orientation angle, and explosive density may vary on a trial and error basis in the hope of getting better results. Problems of overbreak are occasionally encountered implying too much explosives or interaction with adversely oriented joints, as well as burst occurrences implying insufficient destressing. A more recent study by Sainoki et al. (2017) has demonstrated that this practice of preconditioning may not warrant the anticipated stress reduction in and around the mining face. The practice is further restricted by the fact the mid-face preconditioning holes cannot coincide or be close to previously drilled for safety reasons. The orientation of the major principal stress with respect to the drift axis adds to the complexity of the practice. It could result in the need for destressing one side of the face without the other.

Preconditioning has been successfully used in vein mines employing overhand cut-and-fill method (Blake, 1972, Karowski et al., 1979, Hanson et al., 1987), where the crown pillar is systematically destressed prior to mining the next lift. The benefits of destress blasting in narrow vein mines are discussed in detail elsewhere (Mitri, 2001)

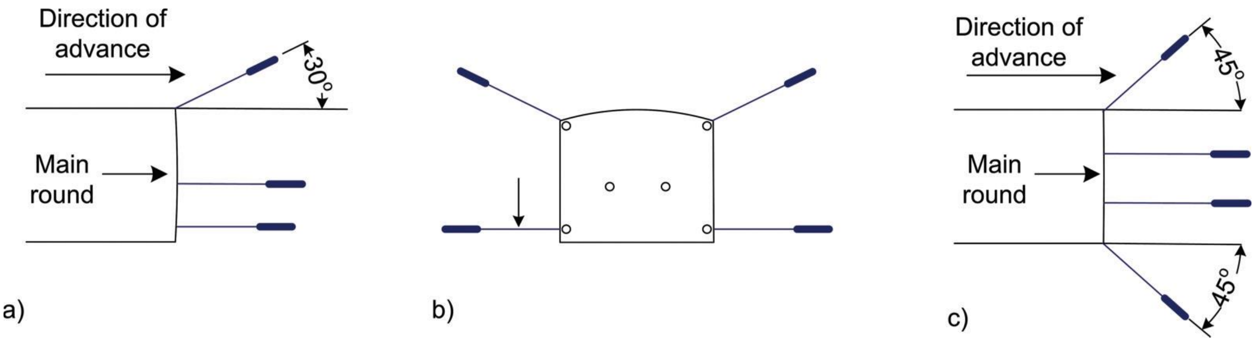


Fig. 2: Typical preconditioning pattern in drift developments (Sainoki et al., 2017) – a) Longitudinal view, b) section view, c) Plan view.

The method of destress blasting for the shielding of a large volume of highly-stressed rock mass relies on the use of large destress blasting slots. This application is quite different from preconditioning in more ways than one. Firstly, the target rock mass is not destressed or preconditioned. Rather it is a nearby slot that extends sufficiently laterally and vertically to create a stress shadow on the target rock mass. Figure 3 depicts the concept with a plan view of an ore pillar that is intended for extraction in high stress environment. Unlike preconditioning, the blast design of the slot is like one of production aiming at complete rock fragmentation.

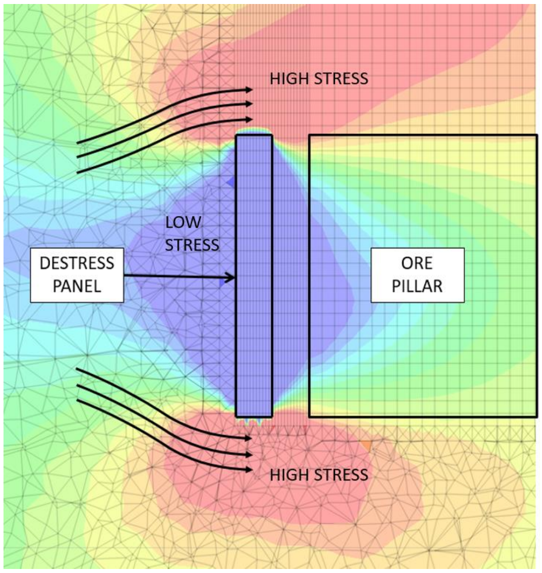


Fig. 3: Plan view of a large scale destress panel for the shielding of an ore pillar (Vennes and Mitri, 2017).

4. Constitutive Modelling

Recognizing that the immediate effect of preconditioning with destress blasting is the creation of rock fractures, Blake (1972), suggested the modulus of elasticity of the destressed rockmass, E_{db}, be a fraction of that before destressing, E, i.e.

$$E_{db} = \alpha E \tag{1}$$

where α is a rock fragmentation factor that ranges from 0 to 1. With this assumption, it was possible to demonstrate the beneficial effects of preconditioning in highly stressed crown pillar (Blake, 1972, Mitri et al., 1988). Tang and Mitri (2000) introduced the notion of a stress dissipation factor, β, to reflect the immediate local stress relief following the blast in the destressed zone. This is expressed as,

$$\sigma_{ijdb} = (1 - \beta)\sigma_{ij} \tag{2}$$

In the above, σ_{ij} is the state of stress before precondition, and the superscript *db* denotes the state of stress after destressing. Note that β ranges from 0 to 1, with the latter representing complete stress relief. Inspired by the work of Donze et al. (1997), Saharan and Mitri (2011) further argued that the parameters α and β should not be the same in all directions. The destressed rock is not uniformly damaged in all directions because the mining induced principal stresses in the rockmass influence the degree of fracturing, with more fractures aligned with the major principal stress, σ_1 and less in the direction of σ_2. The following constitutive model was proposed by Saharan and Mitri (2011)

$$E_{idb} = \alpha_i E \tag{3}$$

$$\sigma_{idb} = (1 - \beta_i)\sigma_i \tag{4}$$

In the above, the subscript "i" denotes the principal stress direction. This suggests that the destressed rock becomes an orthotropic material with 3 rock fragmentation factors $\alpha_1, \alpha_2, \alpha_3$ and 3 stress dissipation factors $\beta_1, \beta_{2,}\beta_3$.

5. Discussion and Conclusion

While the merits of the destress blasting method are conceptually well appreciated by many mines, its efficient implementation in the field has been hampered by the diversity of the available information, the scarcity of well-documented destressing programs, as well as the absence of a dedicated design/analysis method. This has made the destress blasting method more like an art than an engineering science. In this paper, a broad classification of rockburst phenomena is presented as well as the respective destress blasting strategies. Destress blasting applications in metal mines are reviewed, and constitutive models are briefly explained.

The evaluation of the destress blasting efficiency in the field is of utmost importance. Most mines practicing destress blasting rely on microseismic networks to monitor, locate, and characterize large seismic events. One of the simplest indicators of the efficiency of a destress blasting program is to examine the seismic source parameters like the moment magnitude and seismic energy release. The goal of destressing is to "induce" seismicity to help release excess stress and energy in the rockmass and ensure a safer work environment. A simple way to monitor the stress environment is by measuring the deformation of drill holes in the critical zone. Borehole deformation is a direct function of the local stress magnitude and its ovalization is an indication of the orientation of the principal stress. Borehole breakout is equally important; it is indicative of brittle failure of highly stressed rock. The behaviour of the rockmass in high confinement (high compressive stress) tends to alter its behaviour to nearly intact rock. Therefore, knowledge of the basic mechanical properties of the rock helps determine if failure would be violent or ductile. Other more elaborate measures adopted by the mines are the installation of extensometers and stress cells to measure the rockmass response to destressing. Numerical modelling has proven to be an excellent planning tool. Field measurements serve to calibrate and validate the numerical model. Once the numerical model is validated, it can be used as a tool for the evaluation of different destress strategies.

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