Roodekrans Quarry: Blast Proposal report for blasting closer the heritage sites

bme
BLASTING SOLUTIONS

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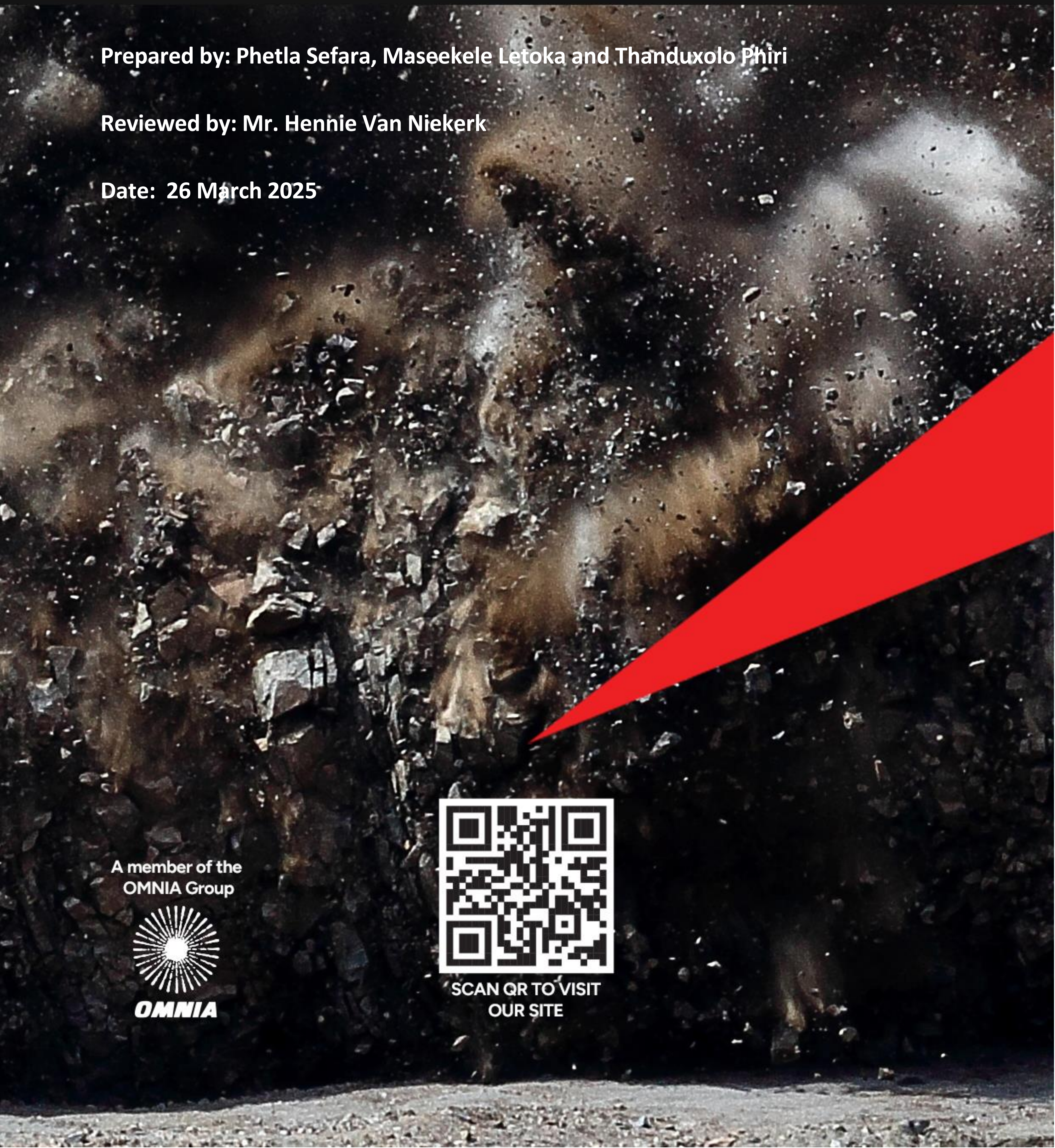

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Disclaimer:

The designs detailed in this document is done in good faith with consideration given to all information supplied. Geological anomalies and ground conditions are not considered. Vibrations and fly rock predictions are calculated using a theoretical model and only based on distance and not direction. By using this design to initiate the blast, the blaster/miner assumes full responsibility and agrees with all aspects of the design. Any discrepancies or anomalies should be clarified before initiation.

1. Introduction

BME technical was requested by Roodekrans quarry to assist with the prediction for blast-induced vibrations, airblast and flyrock for blasting nearby a heritage site. According to the mine personnel the environmental restrictions are 32 graves which were found within the 100m of the blast zone, the mine intends to blast as close as 20m to 40m away from that graveyard. The rock type to blasted is Dolerite – which is used for concrete in civil engineering and in construction industry. Seismograph monitoring will be required to safeguard the structural integrity of nearby structures of concerns and ensure the safety of employees and the surrounding community from potential harm caused by excessive vibrations or noise.

For predictions purposes, BME will rely on the provided parameters that are currently applied by the mine. It must be noted that the normal tolerable vibration for graves is stipulated as 150mm/s. However, in this case the maximum limit will be reduced to 50mm/s due to the condition of the graves. The graves are shown in Figure 1.

Figure 1: Shows the conditions of the graves

2. Blast parameters

The parameters shown in **Error! Reference source not found.**, were provided by the mine.

Table 1: Blast design parameters for the blasts.

PRODUCTION HOLES	
EXPLOSIVE	
Explosive Type	Innovex™ 100
Charge Mass/Meter (kg/m)	9.8
Average Explosive Mass Per Hole (kg)	75
Effective Charge Diameter (mm)	102
Cup Density (g/cm^3)	1.05
Average In-hole Density (g/cm^3)	1.2
BLAST GEOMETRY	
Stemming Length (m)	2.3
Average Hole Depth (m)	10
Average Charge Length (m)	7.7
Hole Diameter (mm)	102
Initiation System	Axxis™ Silver Electronic System
PATTERN	2.3
Burden (m)	2.7
Spacing (m)	
ENERGY	
Average Hole Powder Factor (kg/m^3)	1.2

3. Ground vibrations and airblast predictions

Equation 1 will be used to calculate the blast induced vibrations at various distances away from the blast area. The calculations assumes that each blasthole fires at its own independent delay, with no scatter.

Vibrations predictions can be done using scaled distance formula as shown in equation 1

$PPV = a(\frac{D}{\sqrt{E}})^{-b}$ .... Equation 1

Where PPV stands for Peak Particle Velocities, a and b site constants, D distance to point of concern and E charge mass per delay. Site constants a and b can be conservatively assumed as 1143 and -1.65. Equation 1 is referred to as the scaled distance relationship (Borg et.al.). Based on the in-hole density of 1.2 g/cm^3.

*Prediction for 100m away from the blast area.

$PPV = a\ (D/\sqrt{E})^{-1.65}$
$= 1143(100m/\sqrt{75Kg})^{-1.65}$

The calculated vibrations are 20.2mm/s.

*Prediction for 60m away from the blast area

$PPV = a\,(D/\sqrt{E})^{-1.65}$
$= 1143(60m/\sqrt{75Kg})^{-1.65}$

The calculated vibrations are 46.9mm/s.

*Prediction for 40m away from the blast area

$PPV = a\,(D/\sqrt{E})^{-1.65}$
$= 1143(40m/\sqrt{75Kg})^{-1.65}$

*The maximum generated vibrations at the 40m are calculated as 91.5mm/s, which is higher than the 50mm/s tolerable limit.

The maximum generated vibrations at the 40m exceed the minimum required level for old graves. The blast-induced vibrations must not exceed 50mm/s to prevent the structural damage and compromise the integrity of the graves. Equation 1 is therefore manipulated to obtain the charge per delay that will results in the maximum vibrations of 50mm/s at 50m.

$PPV = a\,(D/\sqrt{E})^{-b}$

$E = D^2 x\,(PPV/k)^{2/-b}$

$= 40^2 \times (50/1143)^{2/-1.65}$

$= 36.04Kg$

The calculation shows that the maximum charge that can be detonated at a given time is 36kg. This then introduces a concept of decking, which is the separation of explosive charge within a blast that will fire at different delays.

The number of decks can therefore be calculated are shown below. Figure 2 illustrate the recommended charging instructions

Number of decks required = Charge column / Required charge for limit of PPVs

= 75Kg/36.04Kg
= 2.0

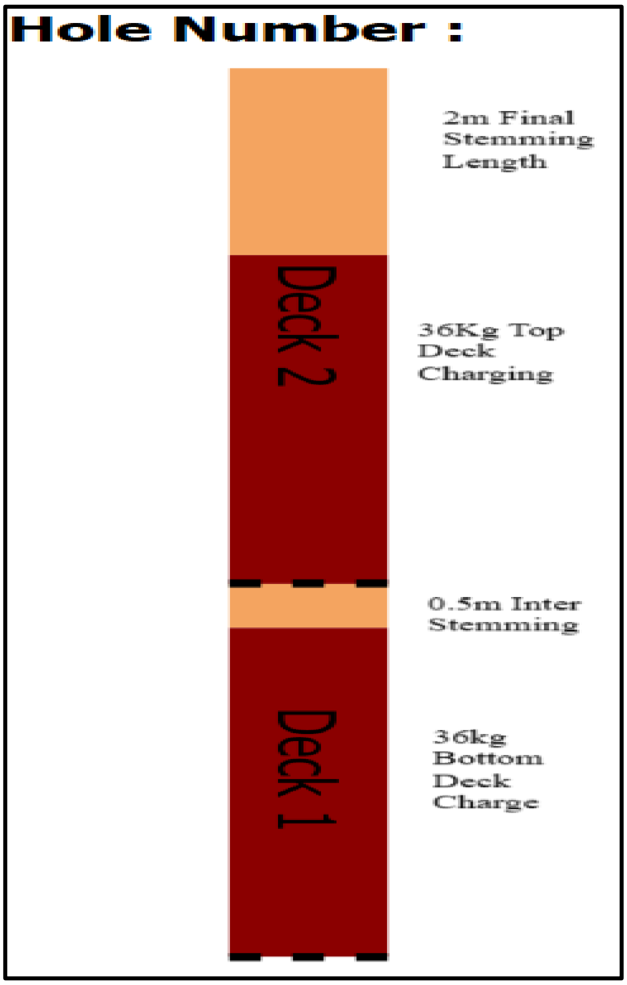

Figure 2: Shows the charging instructions

Mc =P*(D)2/1273

= 1.2*(102)2/1273

= 9.8 kg/m

Where Mc= Linear charge mass in kg/m, p=in hole density, and d=Hole diameter

Average depth = 10 m and stemming length of 2.5m using 102mm drill hole diameter

Charge per hole (charge mass per delay) = L* Mc

=3.7m*(9.8kg/m)

= 36 kg of explosives

Where L = charge length, Mc= Linear charge mass

Powder factor = Charge per hole/(B*S*H)

= (36)/ (2.3*2.4*10)

= 0.58 kg/m

Where, M= charge mass per kg, L = charge length, B= burden, S= spacing and H= Bench height

Peak particle velocity

PPV = a(D/√E)-1.65

=1143(40/√36)-1.65

=49.9mm/s

Where D= distance to source, E= charge mass per delay, a=constant

Average depth = 5.8m and total stemming length of 2m using 102mm drill hole diameter

Charge per hole (charge mass per delay)

= L* Mc

= 3.8m*(9.8Kg/m)

= 37 kg of explosives

Where L = charge length, Mc= Linear charge mass

Powder factor = Mc*L/(B*S*H)

= (37kg)/ (2.3*2.7*5.8)

= 1.03kg/m³

Where, M= charge mass per kg, L = charge length, B= burden, S= spacing and H= Bench height

Peak particle velocity

PPV = a(D/√E)-1.65

=1143(50/√37)-1.65

=51.0 mm/s

Where D= distance to source, E= charge mass per delay, a=constant

The lower powder factor of 0.58kg/m³ at the bottom deck will have courser fragmentation than the powder factor at the top deck. The timing design for block must have an offset between the decks to reduce the blast induced vibration per delay and avoid blast wave arriving at the structure of concern. So, the use of Axxis™ electronic system is regarded pivotal to achieve the desired outcome due to its accuracy and flexibility.

4. Flyrock projections

Flyrock is caused when the explosive energy is too excessive for the burden and the stemming is inadequate to contain the explosives energy within the blasthole or, the energy has vented through a zone of weakness in the rock mass being blasted.

Flyrock is also an important consideration during blasting as this can cause damage/harm to structures, equipment, and people. All control measures possible should be adhered too, to avoid flyrock exposure against people, structures, and Mine equipment.

Normally flyrock can be contained to within 100m of blasting. However, there are exceptions to this and in uncontrolled situations, flyrock can travel beyond 500m. There is an accepted safe distance of 500m for people from a blast in controlled and well-planned blasts (ISEE Blasters Handbook, 17th edition) which considers the unforeseen rock conditions where flyrock range may exceed 100m from the blast. Flyrock prediction studies have been conducted to estimate maximum horizontal distance that flyrock can travel from a blasting area.

Scaled Depth of Burial (SDOB) is one of common methods used to estimate the flyrock range to protect areas of concern. SDOB is the stemming height plus half the charge length contributing to the cratering effect during the hole detonation process (ISEE Blaster's Handbook 18th Edition, 2011); this divided by cube root of weight of explosives contained in a borehole.

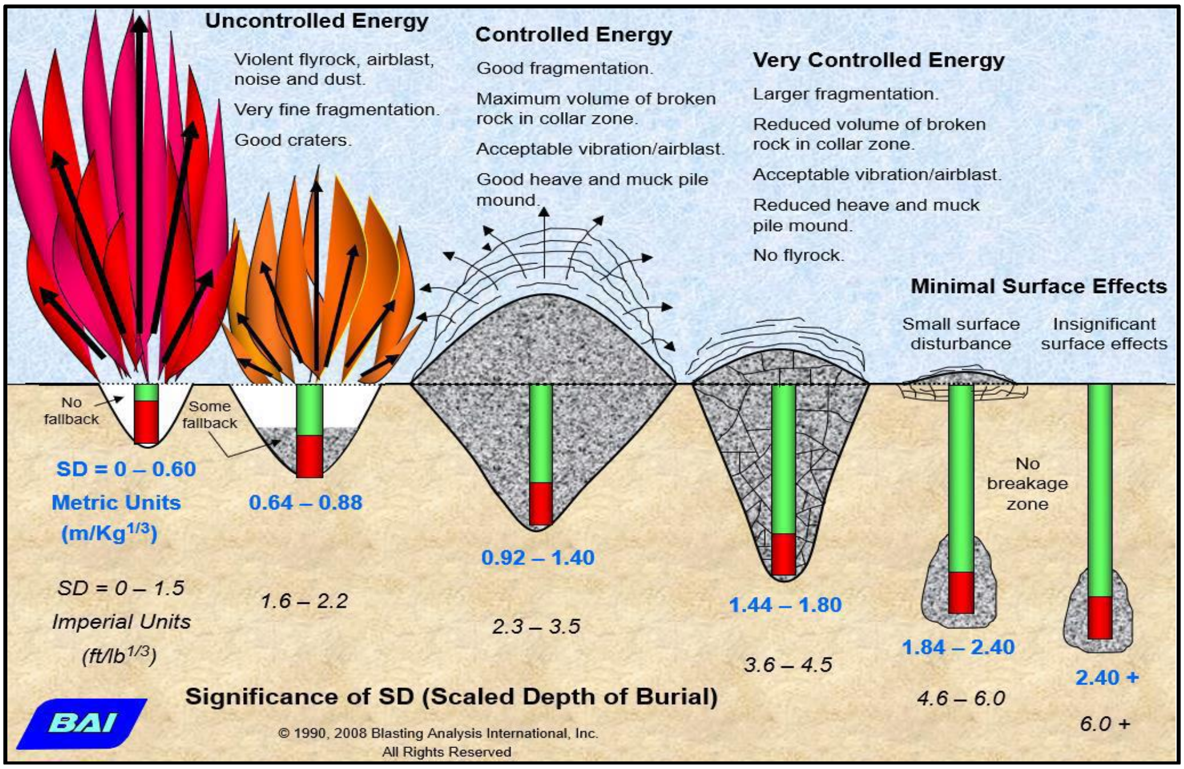

Figure 3: Shows the scale depth of burial.

Recommended range of SDOB for blasting close to sensitive structures is 1.4-2.3m/kg$^{1/3}$.

For the retention and elimination of fly rock, the rule of thumb and scale depth of burial (SDOB) of the current design is calculated.

- SDOB = D/W$^{1/3}$

The SDOB for the diameter of 102mm is calculated using the final planned stemming length of 2.3m. The calculated SDOB for 2.3m stemming length was 1.3, which is slightly below recommended SDOB of 1.4-2.3m/kg$^{1/3}$ for blasting in sensitive areas.

The SDOB is further used to for flyrock prediction:

$$\textit{Flyrock range max} = 11 \times SDOB^{-2.16\ 7} \times d^{\ 0.667}$$

$$= 11 \times 1.3^{-2.167} \times 102^{0.667}$$

$$= 136m$$

Where SDOB is Scaled Depth of Burial and d is borehole diameter.

The estimated maximum distance that flyrock will travel is 136m.

The final stemming length of the is reduced to 2m, due to intermediate stemming for the deck charging.

The SDOB for the diameter of 102mm is calculated using the final planned stemming length of 2m. The calculated SDOB for 2m stemming length was 1.16, which is below recommended SDOB of 1.4-2.3m/kg1/3 for blasting in sensitive areas.

The SDOB is further used to for flyrock prediction:

$$\textit{Flyrock range max} = 11 \times SDOB^{-2.16\ 7} \times d^{\ 0.667}$$

$$= 11 \times 1.16^{-2.167} \times 102^{0.667}$$

$$= 174.36m$$

Where SDOB is Scaled Depth of Burial and d is borehole diameter.

The estimated maximum distance that flyrock will travel is 174m.

In both scenarios, flyrock trajectory might travel beyond the 100m radius. However, the mine personnel mentioned that they are blasting away from the graves, if the blocks to be blasted consists of a free face, the blasted muckpile will tend to take the path of least resistance (into the void) and therefore the likelihood of flyrock projection towards the structures of concern will be reasonably reduced.

5. Conclusions and Recommendations

The biggest risk when blasting close to structures remains fly-rock, vibrations and air blast. Quality control on the bench is very important to ensure that these risks are minimized, strict supervision over drilling, explosives charging, stemming material and final stemming length will be critical for the desired outcomes.

The current blast designs may be applicable to 60m distance away from the graves, However, from 60m to 40m away from the graves deck charging must be introduced. This is done to minimise the blast induced vibrations and flyrock at that heritage site. A crushed aggregate must be used as a suitable stemming material.

If blasting operations advances to 20m away from the graves more decking will be required. Deck charging can compromise the fragmentation of the blast.

Some causes of flyrock, high airblast and ground vibrations are listed below:

- Poor bench preparation - presence of loose rocks
- Poor drilling – short drilled holes, under spaced and over spaced holes, under burdened and over burdened holes
- Inappropriate stemming length and material
- Overcharged holes
- Out of sequence timing

Some measures to eliminate flyrocks minimise high airblast and ground vibrations are:

- Disciplined bench preparation (Proper cleaning)
- Accurate drilling
- Single hole initiation by using the Axxis™ Silver Electronic System
- Avoid overcharging of holes
- Recommend covering the blast surface with blast shield, blast mats, conveyor to minimize the possibility of flyrock and high airblast.
- Introduce deck charging with the aim of offsetting timing design to ensure single hole firing per charge reduce the intensity of the blast wave vibrations arriving at the structure of concern