8TH DRILL & BLAST DOWN UNDER CONFERENCE 2024

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Flyrock from Charges in Blasted Muckpile

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Abstract

In open-cut mining operations, lightning events pose significant safety risks due to the potential detonation of misfired explosive charges, leading to flyrock projection. Typical safety protocols require evacuating personnel from areas within a standard distance of misfired holes, regardless of the explosive charge's characteristics or depth of burial. This requirement often results in substantial productivity disruptions. This study aimed to determine the necessary exclusion zones around misfired holes in blasted muckpiles, comparing these to the conditions for charges fired in undisturbed rock.

A field trial was conducted at a Bowen Basin Coal Mine to measure the projection distances of various charges in blasted ground, varying in length and burial depth, and to compare these distances with previous trials conducted in undisturbed rock. The findings revealed that the flyrock range for a charge in blasted muckpile is approximately one-third of that in an insitu rock mass. This result supports the possibility of decreasing lightning exclusion zones around misfired charges in blasted muckpiles, potentially minimising production losses during adverse weather conditions. Furthermore, this study deepens our understanding of the mechanisms influencing flyrock production, contributing valuable insights into safety management in mining operations.

Introduction

Misfires can be an unfortunate reality of blasting, and managing them within the mining production cycle can be challenging. Typically, in coal mining where blasted benches can be +30m deep, it is not practical to campaign the remediation of a misfire without significantly altering the dig sequence and as such, misfires can sit in blasted muckpiles for extended periods. When this occurs over the wet season, the misfire will be exposed to periodic lightning storms and are at risk of an unplanned initiation from lightning strike. As such, exclusion zones are placed around misfires during lightning events to ensure personnel are not exposed to flyrock resulting from a misfire detonation.

Typically, these exclusion zones are a generic distance and the same as those for a production blast resulting in a large area surrounding the misfire being cordoned off and production ceasing. Where a number of tests within the industry have been conducted into the maximum flyrock projection distance for an explosive charge in undisturbed rock, the projectile distance in a broken muckpile is not well understood.

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This test work sought to determine what the expected projectile distance is for various charges and depths of burial in a simulated misfire condition and compare this to those of an undisturbed rock mass. This information can then be used for the purposes of modelling the maximum predicted flyrock range for any misfire that may be encountered in the future.

Background

This program of testing comes on the back of previous test work conducted onsite in an undisturbed rock mass. This test work was for the purposes of validating the flyrock model in the Paradigm software, which is underpinned by the Maximum Flyrock Range equation published by C.McKenzie (2009) (Equation 1) and was being utilised onsite to model the maximum predicted flyrock ranges of production blasts.

$$Range_{max} = 11 \times SDOB_m^{-2.167} \times d^{0.667}$$

Equation 1. Maximum Flyrock Range Calculation

Where:
$Range_{max}$ = Maximum flyrock range (m)
SDOBm = Scaled Depth of Burial (meters/kilogram$^{1/3}$)
d = Hole diameter (millimetres)

An opportunity was identified to quantify the differences in maximum projection distances for charges in broken ground to that in an undisturbed rock mass and apply these learnings to the minimum clearance distances being applied to misfires.

Field Testing

A series of single-hole firings were conducted in controlled conditions designed to simulate that of a misfired charge. From these firings, the resulting flyrock distances were measured and the fragment sizes recorded.

To ensure the flyrock distance were captured accurately, suitable test sites were established to ensure that any flyrock greater than 60mm could be identified. The chosen sites were large open areas, and where there were multiple holes being fired in the same test event, a distance of at least 50m between holes was maintained to ensure there was no overlap of flyrock footprints. Each site was levelled and well graded to ensure that flyrock projections could be distinguished.

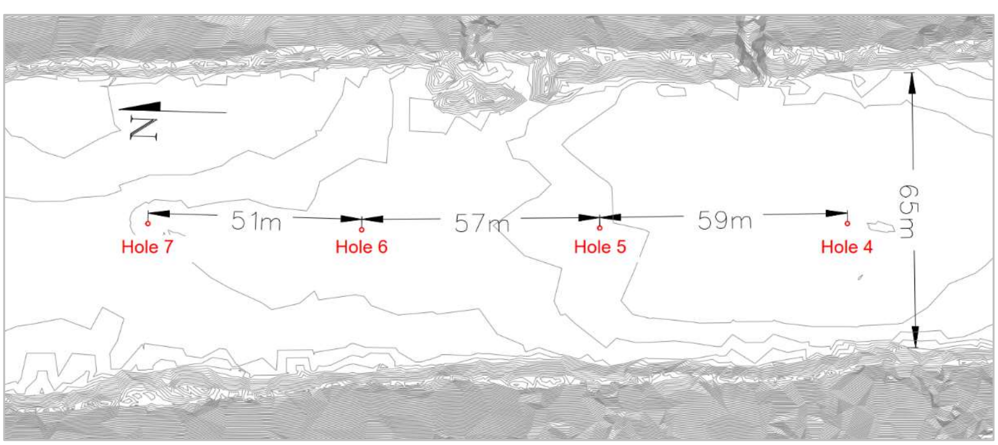

Figure 1. Test site layout

In total, 10 vertical holes were drilled with a 251mm diameter, at depths varying from 8.5m – 17m. The majority of holes were drilled into waste rock dumps for ease of logistics and a further 3 into blasted muckpiles. These holes were loaded with an explosive charge of either ANFO (Ammonium Nitrate Fuel Oil) or 30% HANFO (Heavy Ammonium Nitrate Fuel Oil) blend at 1.1g/cc and primed with 2 electronic detonators and 2 400g booster. They were then stemmed using a good quality 20-30mm basalt aggregate, to a burial depth ranging from 3m to 7m.

Each hole was fired and footage of the events recorded via drone. Once fired, the flyrock fragments at the outer limits of the flyrock footprint were marked, given an ID, their size measured and recorded photographically and the location recorded via DGPS (Differential Global Positioning System).

Figure 2. Flyrock fragment size recorded

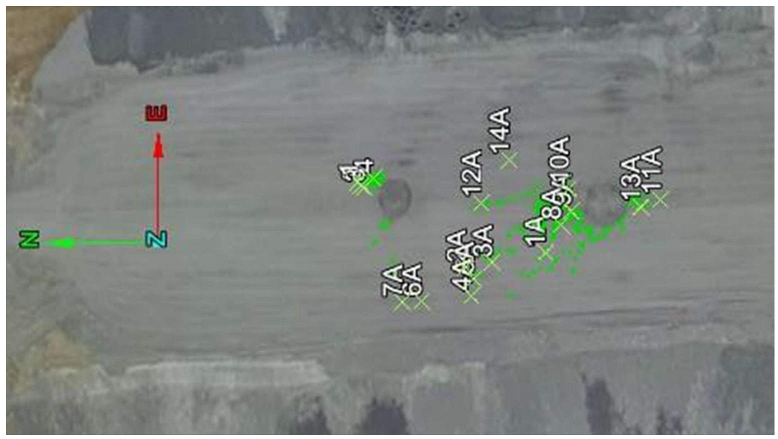

Figure 3. Surveyed locations of flyrock fragments

Observations

No flyrock ejections were observed from any of the holes that had stem lengths greater than 4m. Hole 1, which had a stem length at 7m, formed a large sub-surface cavity at a depth of 6.5m (Figure 5). Holes 2, 3 & 4 also created cavities however these then collapsed creating a sinkhole at the surface (Figure 6).

Figure 4. Hole 1 post blast collar - no flyrock, stemming ejected

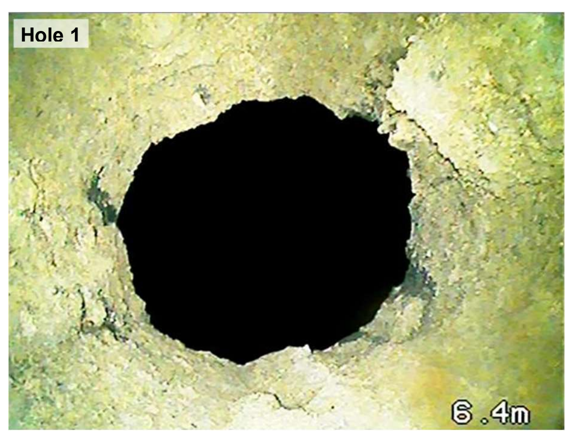

Figure 5. Hole 1 downhole camera footage post blast at 6.4m showing open void below stem height

Figure 6. Crater generated by Hole 4

Figure 7. Hole 9 flyrock ejection

Holes 6-10 generated flyrock of varying maximum distances as summarised in **Error! Not a valid bookmark self-reference.**.

Table 1. Summary of Test Results

Hole	Location	Hole Diam. (mm)	Depth (m)	Charge Length (m)	Explosive Charge Type	Stem Length (m)	Comments
Hole1	Waste Rock Dump	251	17	10	ANFO	7	No Visible flyrock - collapsed crater formed
Hole 2	Waste Rock Dump	251	16	10	ANFO	6	No Visible flyrock - collapsed crater formed
Hole 3	Waste Rock Dump	251	15	10	ANFO	5	No Visible flyrock - collapsed crater formed
Hole 4	Waste Rock Dump	251	14	10	ANFO	4	No Visible flyrock - collapsed crater formed
Hole 5	Waste Rock Dump	251	-	-	-	-	Hole blocked, no charging
Hole 6	Waste Rock Dump	251	13	10	ANFO	3	Flyrock max dist 54.8m
Hole 7	Waste Rock Dump	251	13	10	ANFO	3	Flyrock max dist 8.2m
Hole 8	Blasted Muckpile	251	10.7	7.7	30% HANFO	3	Flyrock max dist 42.4m
Hole 9	Blasted Muckpile	251	8.5	5.5	30% HANFO	3	Flyrock max dist 9m
Hole 10	Blasted Muckpile	251	8.5	5.5	30% HANFO	3	Flyrock max dist 5m

Results

From the data that was collected during the field testing phase, the flyrock distance and fragment size were scaled to give the dimensionless parameters of Normalised Maximum Range and Scaled Fragment Size as a means of comparing data from various scaled depths of burial. The methodology for scaling this data is as described by McKenzie (2022).

As the site has done previous test work in an undisturbed rock mass to validate the Maximum Flyrock Range calculation (Equation 1) proposed by McKenzie (2009), it was then possible to compare the results from the trials in broken ground to this equation. As shown in Figure 8, the maximum flyrock range of the charges in broken ground is significantly less than that of those in an undisturbed rock mass; approximately one-third of the range.

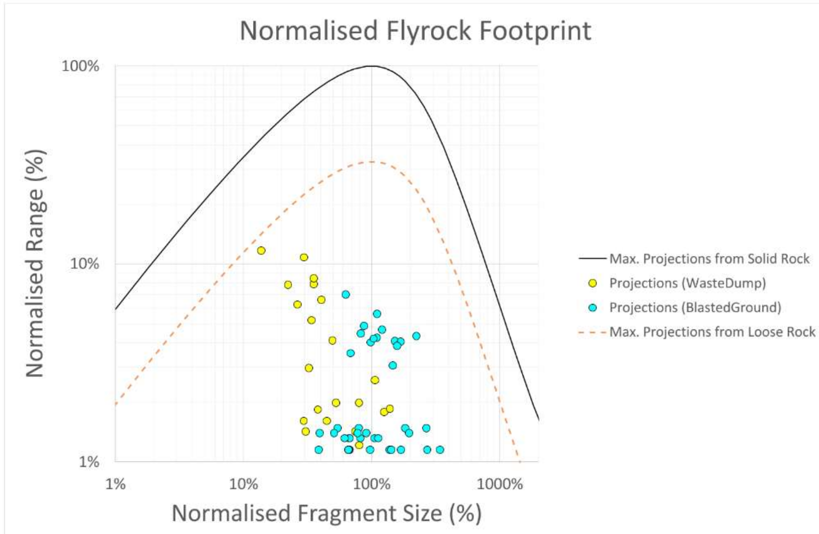

Figure 2. Comparison of maximum flyrock projection distances in loose rock to those in undisturbed rock-masses

These results show that the deformation of the loose muckpile around the hole at the time of firing is so great that the pressure applied to the base of the stemming is considerably lower than that in an intact rock mass. This reduced in-hole pressure is resulting in significantly lower projection distances.

The Model in Practice

Once a misfire has been identified, all the relevant as-loaded data is collected and input into the Paradigm software. A 3D terrain model of the area is imported in order for the software to calculate the minimum burden on the misfired charge and to calculate the intersection of flyrock "shroud" with the terrain surface.

As the Paradigm software is designed for the modelling of a projection distance in an undisturbed rock mass, the model needs to be "calibrated" for a broken rock mass. The software does not yet have a variable that can be adjusted for the purposes of calibration, it does however have a Factor of Safety (FoS) field which was used for this purpose. From the field work that was conducted it was determined that the maximum projection distance in a broken rock mass was one-third of that in an undisturbed rock mass therefore any predicted flyrock range generated by the software needs to be multiplied by 0.33.

Given the potential for the depth of burial of the misfire to have changed during blasting, it was deemed prudent to apply a Factor of Safety (FoS) of 1.5 to the test finding of 1/3 giving a model calibration of 0.5. (0.33 x 1.5 = 0.4955).

As the misfire is likely to have moved within the muckpile during blasting, an educated assessment of the likely horizontal movement is made by reviewing the drone footage of the blast along with the pre and post-blast topographies. This distance is then to be added to any exclusion distance applied to the misfire.

In the following example, a misfired presplit hole has been partially uncovered and the flyrock model run using the adjusted parameters for a broken rock mass generating a predicted flyrock footprint of 360m. Prior to this test work being done, a standard 600m exclusion zone would have been placed on this misfire resulting in a larger area of the mine operation being forced to shut down in the event of lightning.

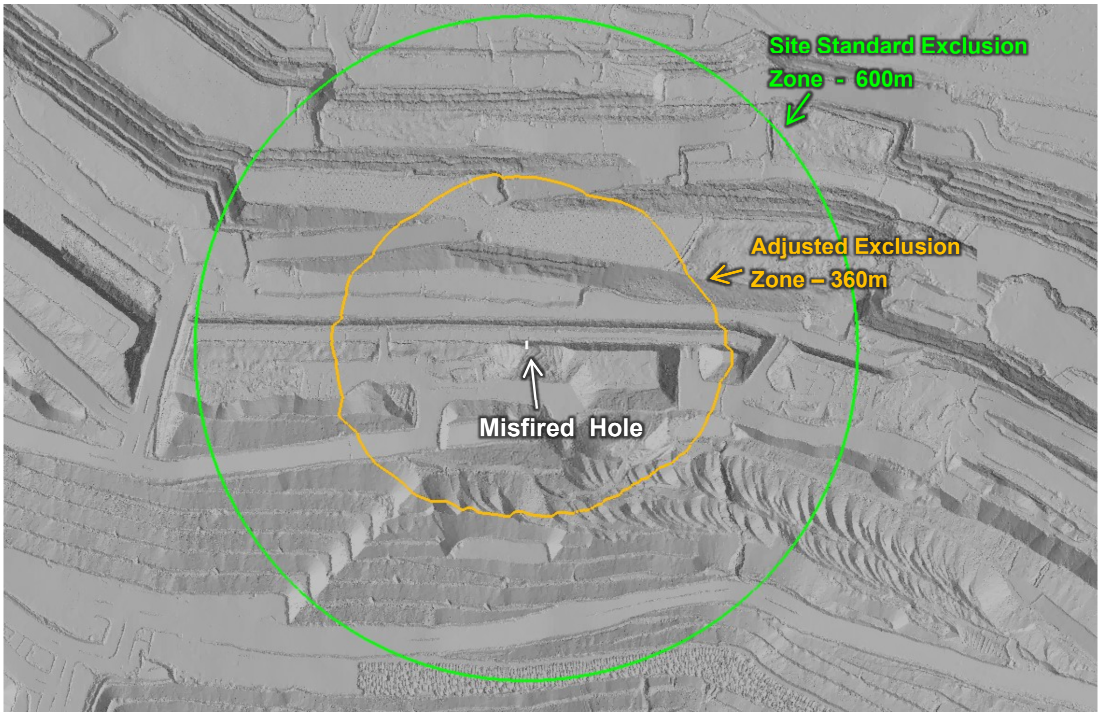

Figure 3. Modelled flyrock footprint for misfired charge

Opportunities

The majority of the test holes for this trial were located in waste rock dumps as setting up tests in blasted muckpiles can be hard to schedule around other mining activities. Although the test conditions of waste rock dumps is similar to that of a blasted muckpile, more testing in post blast conditions would be advantageous to support the findings from the test work conducted to date.

Conclusion

This field trial has shown that flyrock from misfired charges in blasted muckpiles only travelled a third of the distance that undisturbed rock travels. These results indicate that current safety exclusion zones may be larger than necessary when dealing with misfires in muckpiles. By adjusting the predicted flyrock ranges based on this finding, we can potentially reduce unnecessary downtime and improve productivity without compromising safety. Further testing in blasted muckpiles will help solidify these conclusions, offering a more practical approach to managing misfires and keeping mining operations running smoothly.

References

C.K. McKenzie; *Flyrock Range & Fragment Size Prediction*, 36th Annual Conference, International Society of Explosives Engineers, Denver, 2009

C.K. McKenzie; *Flyrock Model Validation and Application*, 49th Annual Conference, International Society of Explosives Engineers, Las Vegas, 2022.

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