Utilization Of Aerial Drones To Optimize Blast And Stockpile Fragmentation

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Abstract

This document introduces the use of drone generated aerial photography to collect and analyze fragmentation data for both muck piles and post crusher stockpiles in order to support the continuous improvement process. In tandem with photo analyses software, drone imaging gives mines and aggregate sites a fast, accurate and economical method of benchmarking and optimizing the process of size reduction to spec.

Introduction

The introduction of the following methodology and technology is driven by the ***mine to gate*** continuous ***Improvement Process***. The impact of ore size distribution along the process has been proven to be critical to quality as well as cost thru the performance of all the components (loading crushing milling and kiln operations), ore yield and meeting the final product specification. Improvement is linked to maximizing utilization of key components so mines and quarries strive to deliver ore to the point of entry in a state that would contribute as much as possible downstream. The higher the compatibility between the ore's controlled variables and the plant's requirements the better the productivity, cost and usually the quality of the final product. To overcome the fragmentation's high standard deviation and lack of compatibility "that can't be avoided", plants compensate by implementing expensive processes solutions. Our goal to produce the ideal feed requires we calibrate the pre-process handling of the ore - the blasts. Correlating between geology, blasting parameters such as pattern, timing, explosive load, hole information and measuring the results in place is key to that calibration. The path to continuous improvement is:

1. Creating a "situational awareness" – a 360-degree picture of the parameters.

2. Understanding the muck-pile, fragmentation, shape and density by zone location and the root cause for this occurrence.

3. Making a change (decision).

4. Measuring the impact of the change and comparing it to a benchmark, and adjusting/pushing the performance envelope.

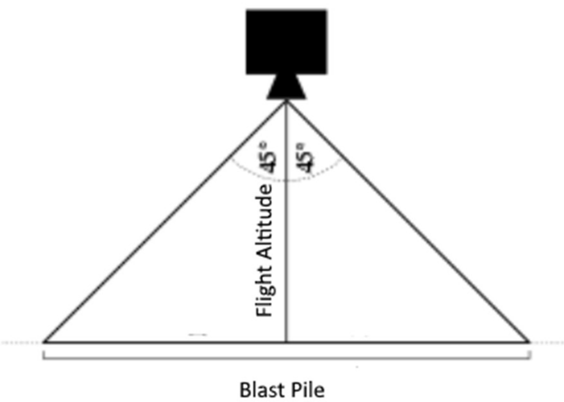
Today, for the first time, we are able to see the blast fragmentation from overhead utilizing aerial drone photography. Location-specific fragmentation data is one of the important building blocks in the process of putting together that 360-degree picture. With the advancement of UAS (Unmanned Aircraft System) technologies, operations are realizing the benefits of new capabilities including aerial particle size analysis through photoanalysis, using existing UAS photographs taken for surveying and 3D profiling. Utilizing this tool allows us to make changes that will help us in future blasts, and it can also allow us to react to the current conditions by adjusting the mucking plan.

This is a first step in creating a comprehensive tool that will assist us not just in understanding current blasting and stockpile feeding procedures, but also making real-time educated decisions based on fragmentation data and we have taken it.

Collecting Images and Fragmentation Data

Drone Configuration

With the rapid development of drone technologies capable of carrying more weight and flying longer, higher resolution mounted cameras and the opportunity to fly longer overlap patterns to achieve high quality orthomosaic (stitched) images allows for the detection of finer particle sizes, and more precise analysis of the material pile in general.



When selecting the drone used for collecting blast fragmentation data, it is important to note that the resolution of the camera in conjunction with the altitude of the drone will have impacts on the minimum particle sizes that can be delineated using photoanalysis software. After identifying the limitations of both commercial and industrial-grade drones with various cameras, the following figure and formula will help identify the minimum/maximum particle sizes that can be analyzed when flying over a blast pile:

Assuming a 45 degree camera field of view, the ratio of the flight altitude to the blast pile width is 1:2. Flying at 150 feet (45.72 meters) will get you an image analysis area of approximately 300 feet (91.44 meters).

In the case of the Lafarge Bath Quarry, the drone used was capable of taking an image with a resolution of 3992 pixels wide and 2242 pixels high. This translates into 9 megapixels.

By dividing the blast pile width by the pixel width, you are able to get an estimation of the minimum size that can easily be analyzed with minimal manual editing inside of the photoanalysis software. For the aforementioned figures, the software used was capable of comfortably analyzing material sizes down to approximately 1.3527 inches (34.36 millimeters).

After attempting to fly the blast pile at Lafarge – Bath Quarry with a DJI Phantom 3 and DJI Phantom 4, it was determined that commercial grade drones are powerful enough to capture the images necessary for the fragmentation analysis; however, it is recommended that using commercial drones in conjunction with orthomosaic software to stitch multiple images together will vastly increase the accuracy and minimum resolvable particle size. With the study, there was a minimum resolvable particle size of approximately 1 inch. In order to get down to the 3/8 inch key performance indicator that limestone and cement operations are interested in achieving, Orthomosaic images with 20% overlap will allow for sub-1/4" analysis results. Using a commercial grade drone is a very economical way for mining operations to get a good representation of the blast with the ability to make changes and track improvements in blasting performance.

The Photoanalysis Process

Sizing analysis of muck piles has been done for many years. A detailed review of this method is given by John A. Franklin, and Takis Katsabanis. (Measurement of Blast Fragmentation, Fragblast Workshop, 1996).

The photoanalysis process involves capturing images of the fragmented rock in question and uploading these images into the fragmentation analysis software. Orthomosaic imaging software allows for an overlay scale to be placed anywhere in the image after the flight takes place. This scale is used as a reference inside of the image, and is crucial for the analysis to take place.

Figure 2: 3D image of the blast pile used for fragmentation analysis

The photoanalysis software's automatic edge detection parameters delineate the particles within the image based on the defined edges of the particles. In the case of this technical paper, it took approximately ten seconds to run the analysis, and approximately seven minutes of manual edits to these images to ensure an accurate analysis.

After editing, the software outputs the particle sizing data into a percent-passing format for up to 17 customizable size classes.

Unlike traditional photoanalysis methods where an employee walks to a blast pile, places a measurement device in the blast pile's area of interest and captures images standing perpendicular to the material, drone imaging allows for the user to capture aerial images of the same pile, and use orthomosaic imaging to automatically set the scale inside of the image. It should be noted that the drone flights were controlled from approximately 150 feet away from the blast piles, further confirming that this method of collecting particle sizing is much safer than other methods that require manually placing scales on the pile in question.

Blast Pile Benchmarking and Optimization

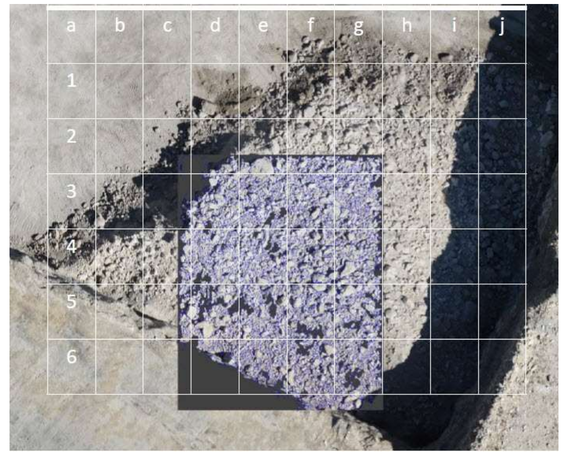


Figure 3: Grid overlay used to identify specific areas in the blast that need attention. The fragmentation 'nets' can also be seen.

Having the fragmentation of the entire blast pile allows an operation to begin benchmarking procedures in the hopes of finding ways to improve performance. To break down blast performance for each shot, the authors found that it is advantageous to implement a grid overlay when completing the analysis of blasted material. By doing so, the interested parties will be able to identify the following:

What specific zone of the blast provided acceptable fragmentation, and how can we reproduce these results?

Where are the problem areas inside of the blast, and what caused these areas to be coarser? (Stemming, initiation, hole spacing, etc.)

Three different grid areas in the blast pile image were identified as having fine, mid-sized or coarse material when visually inspecting the orthomosaic image generated by the drone. Once identified, these areas were analyzed inside of photoanalysis software to get size distributions.

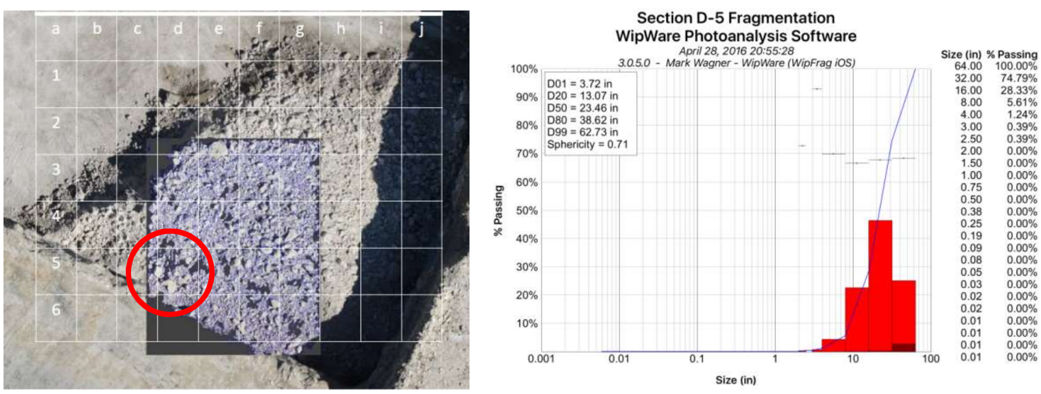


Figure 4. Section D5 identifies a coarser section of the blast, and its associated distribution curve

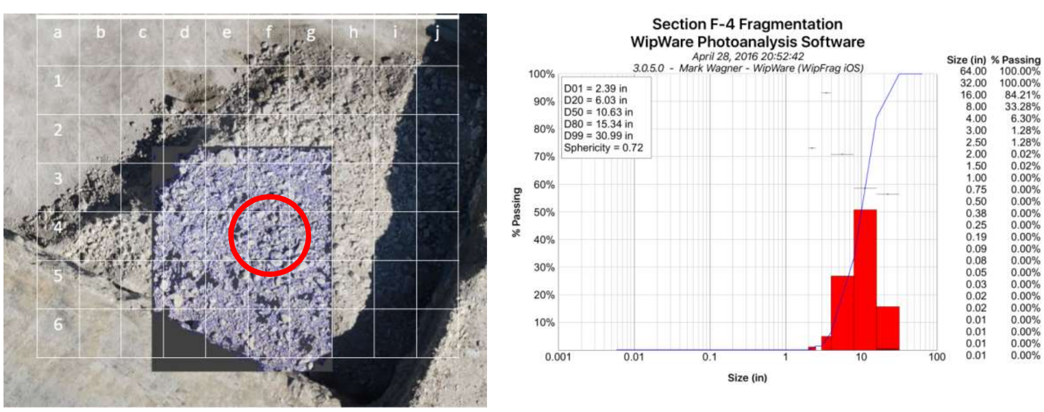


Figure 5: Section F4 identifies a finer portion of the blast and its associated distribution curve

In addition to testing these three areas of the blast pile separately, the particle sizing results can also be merged to help get the "full picture" look at the blast pile fragmentation and a comparison against future blasts. Using the primary crusher specifications as a guideline, zones can then be created inside the analysis results to track improvements and optimize material size being fed into the crusher. In this case, we identified the green area as a "no-work zone", where the primary crusher does not need to actually crush this material; a yellow zone "crush zone" where the primary crusher begins actively breaking down material, and a red "danger zone" where oversize material is getting into the primary crusher.

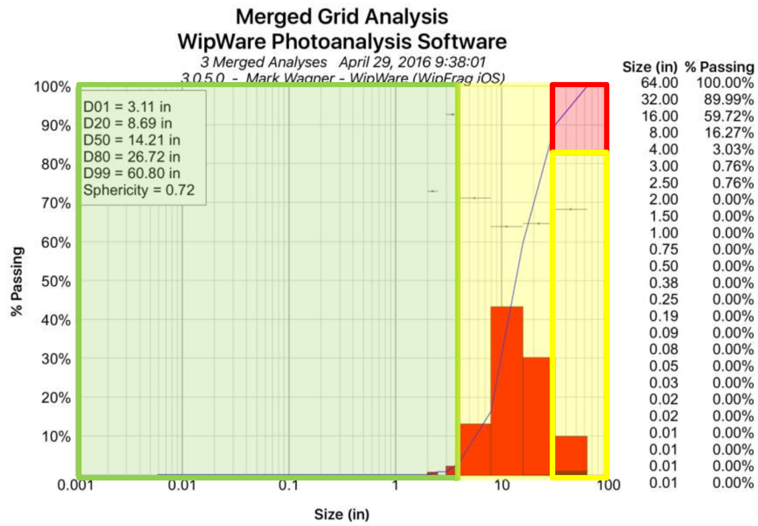


Figure 7: Merged grid analysis results can be used to benchmark where the operation is in terms of ideal fragmentation, and will allow operations to see improvements on future blasts

Utilizing The Data

At this stage we are ready to integrate this data to the CI process. After the initial task of photographing the pile and the shot has been completed and fragmentation analyses has been completed we go to the next phase – setting the data in a format that allows better understanding and correlation to upstream impacting factors and downstream impacted factors. Those could be an issue to deal with or an opportunity to grasp. After we have completed this step we can seek actions. The steps in this process are:

1. Setting a reference grid covering as much of the pile as possible in order to
2. reference and collect all of the anomalies and seemingly
3. Inconsequential data.

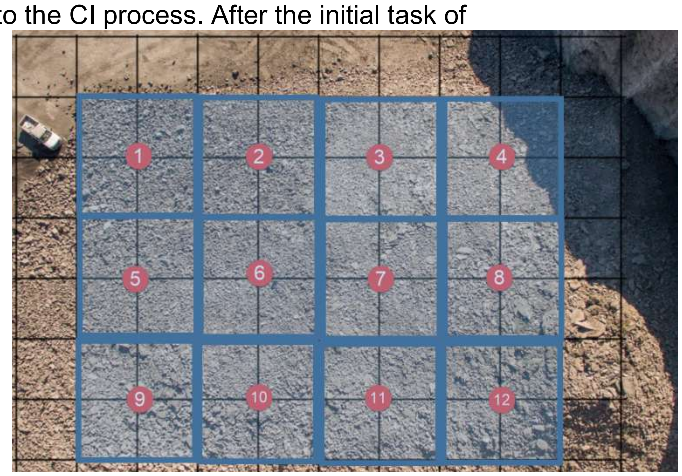


Figure 8: Setting up a grid pattern is crucial in being able to reference where the coarser and finer fragmentation came from when blasted.

4. Visually reviewing the pile for anomalies in shape and fragmentation. In the first case (the picture on the left) two anomalies were spotted, a high ridge (marked in yellow) and a peek marked in red. Those anomalies represent a higher density zone in the pile that might contain larger material. This event should launch an RCA that when reviewed with the shot and drill report can produce action items. In the second case a quick view of the picture (the picture on the right) will assist in identifying fragmentation anomalies by highlighting the very large size rock in yellow. This will assist in focusing on problematic areas.

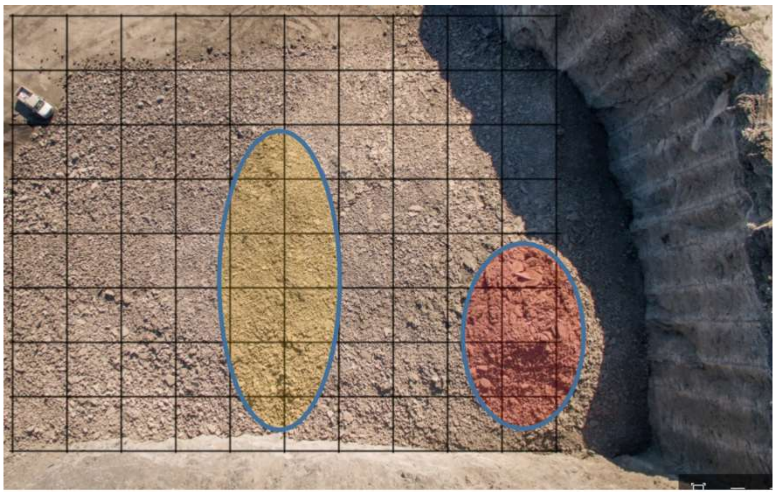


Figure 9: By studying the drone image, the user can identify peaks (red) and ridges (yellow) in the blast.

Figure 10: Fragmentation grids can be colour coated based on sizes, and can identify areas in the pit that showed finer and coarser fragmentation

5. Analyzing the fragmentation of each zone separately and looking for both the individual zone analyses and the combined fragmentation curve.

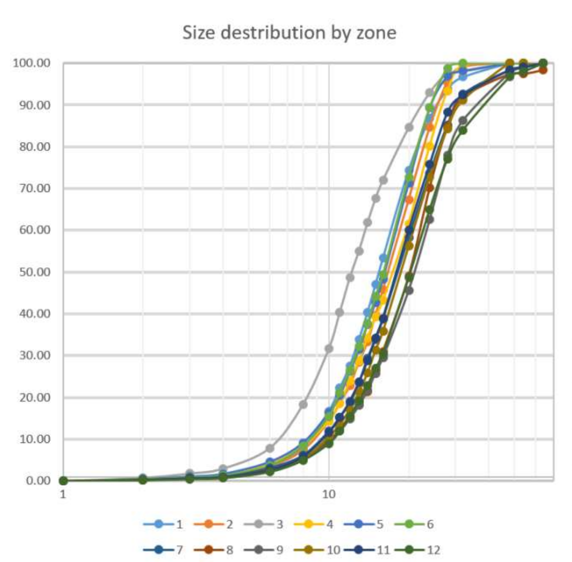


Figure 11: Distribution curves from the twelve separate zones for quick identification

6. Comparing the pile fragmentation to the BlastCast model. The more accurate we become utilizing the model the greater our confidence in its results, allowing us to use it as a planning tool (scenario-builder).

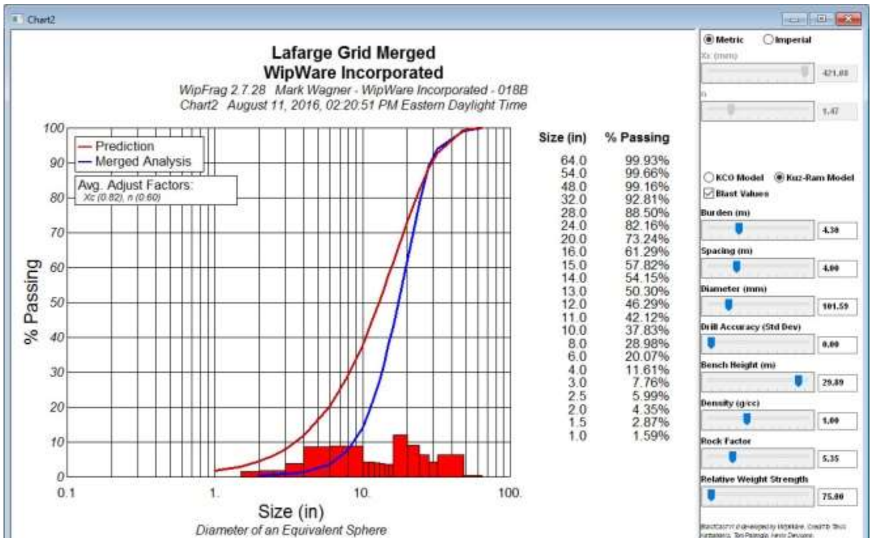


Figure 12: Blast Prediction models will allow users to tweak procedures in order to achieve fragmentation within the desired crusher specifications.

7. Defining the primary crusher benchmarks (in this case a APPH1615 Hazemag Primary impactor). This crusher is a no bypass machine closed to 2”.

Crusher Specifications

Model	Capacity Tons/Hour (Tonnes)	Power Requirements Hp (Kw)	Inlet Size in. (mm) (H x W)	Maximum Feed Size in. (mm)	Rotor Size in. (mm) (D x W)	Weight Lb. (Kg)
APPH-1010	125 (115)	150 (115)	35 x 40 (890 x 1020)	20 (500)	40 x 40 (1000 x 1000)	28,000 (12,725)
APPH-1013	175 (160)	200 (150)	35 x 54 (890 x 1360)	20 (500)	40 x 52 (1000 x 1340)	34,100 (15,500)
APPH-1313	250 (230)	250 (185)	43 x 54 (1092 x 1360)	25 (635)	52 x 52 (1340 x 1340)	42,300 (19,200)
APPH-1315	350 (320)	400 (300)	43 x 60 (1092 x 1360)	25 (635)	52 x 59 (1340 x 1500)	46,000 (20,900)
APPH-1320	450 (400)	500 (375)	43 x 80 (1092 x 2030)	25 (635)	52 x 79 (1340 x 2000)	58,600 (26,600)
APPH-1515	400 (360)	500 (375)	47 x 60 (1092 x 1360)	32 (812)	59 x 59 (1500 x 1500)	49,200 (22,300)
APPH-1615	450 (400)	500 (375)	47 x 60 (1092 x 1360)	36 (915)	64 x 59 (1600 x 1500)	59,600 (27,090)
APPH-1620	600 (550)	600 (450)	50 x 80 (1270 x 2030)	36 (915)	64 x 79 (1600 x 2000)	77,100 (35,045)
APPH-1622	650 (600)	700 (525)	50 x 89 (1270 x 2270)	36 (915)	64 x 88 (1600 x 2200)	82,600 (37,545)
APPH-1630	800 (730)	800 (600)	50 x 119 (1270 x 3020)	36 (915)	64 x 118 (1600 x 3000)	104,700 (47,590)

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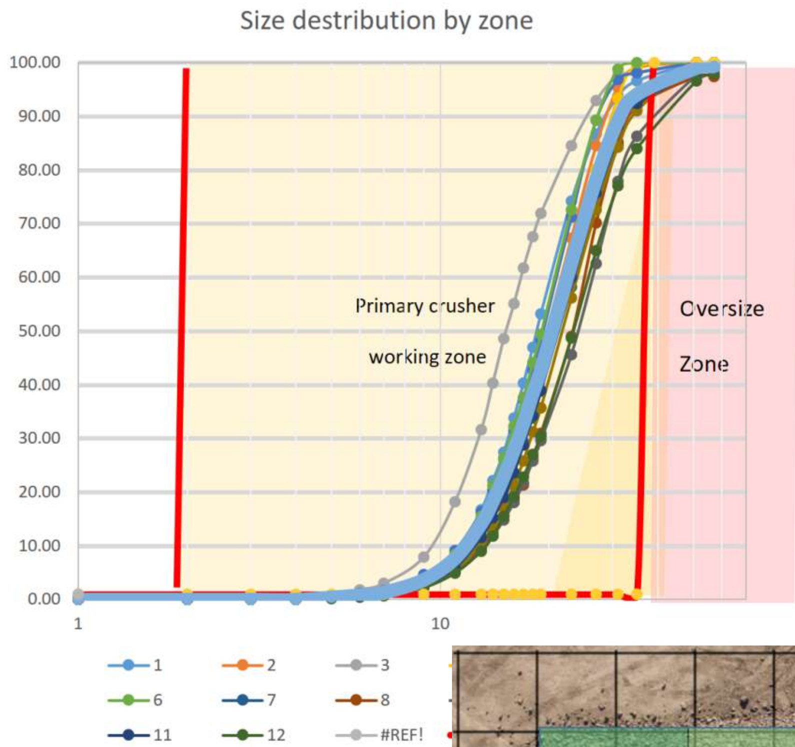
8. Overlay the primary crusher benchmark information over the zones fragmentation analyses: this crusher top-size intake is 36”. The secondary Canica VIS crusher top size is 2 Inches (50.8 millimeters), therefore the working zone of this crusher is between 36 Inches (914.4 millimeters) and 2 Inches (50.8 millimeters).



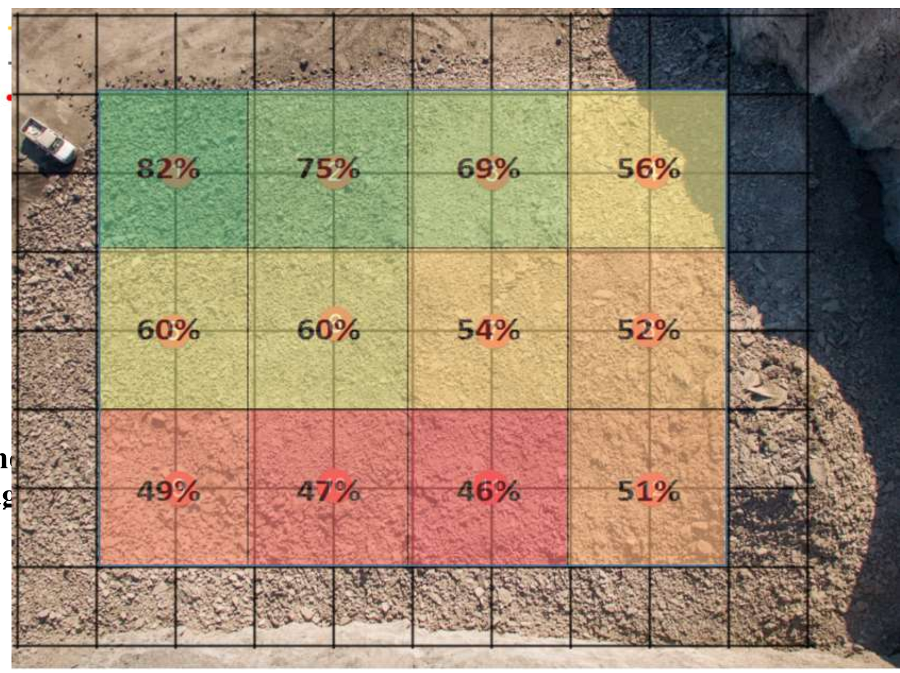


Figure 14: Overlaying the crush
to identify undesirable blast frag

9. Creating a fragmentation compatibility map by zone to show the correlation between the primary crusher capacity and the shot outcome. In this case we used 10 Inches (254 millimeters) and 1 Inch (50.8 millimeters) as the bottom size.

Figure 15: The compatibility zones allow users to identify what material is best suited for the crusher specifications

10. Reviewing the shot report correlation to the fragmentation by zone outcome.

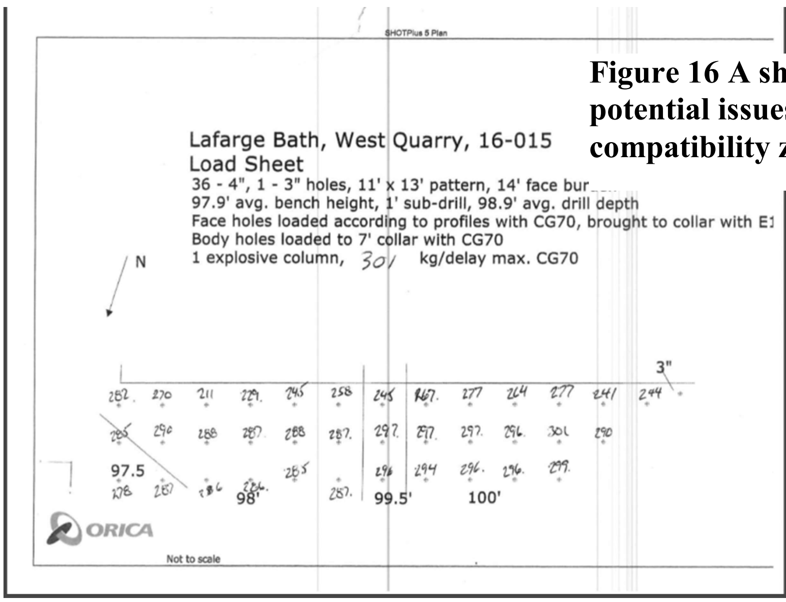


Figure 16 A shot report allows the user to identify potential issues with the blast as they relate to the compatibility zones

11. Utilizing an automated conveyor belt particle sizing system installed post primary crusher, we obtain the crusher run size distribution and correlate it to the secondary crusher benchmarks (Canica 3000 HD DD).

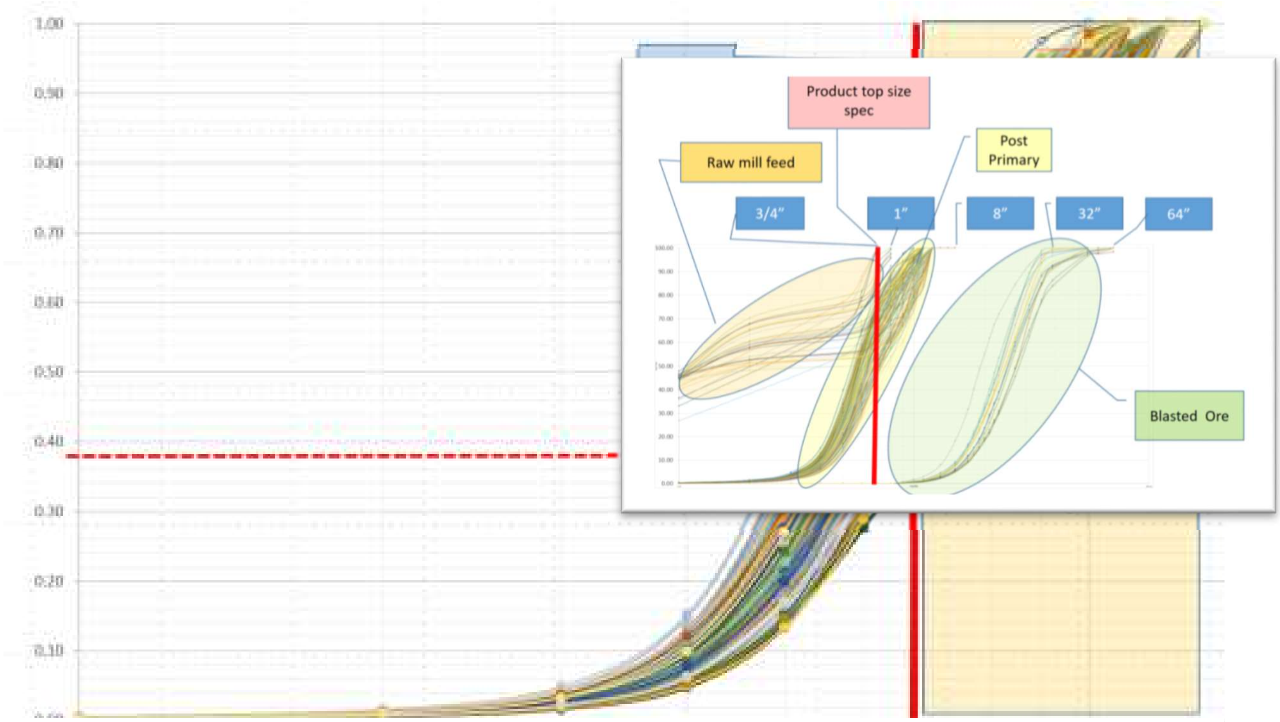


Figure 17 Tracking particle sizes as they pertain to the secondary crusher specifications

12. By compiling the data from three major phases of the mining process we can see the contribution each phase makes. (See Figure 18).

13. Complementing the data are the benchmarking and scenario building tools such as the plant optimization tools (in this case AggFlow and BlastCast). (See Figure 19.)

Figure 18 By comparing the fragmentation data from the blasting and crushing zones tracked, we can begin to identify the contribution that each phase makes.

14. The next step after data is collected, analyzed and put in the proper dashboard-like template is to use it in the continuous improvement process driving conclusions and creating action items (and updating KPI). On top of that we can validate our assumptions and guidelines by looking at the trends. As this data is continuous and automatically generated we can take actions as we go along (changing drill patterns and crusher settings). The opportunities that arise range from what can we do better on the upstream to meet the targets or can we improve on the downstream side

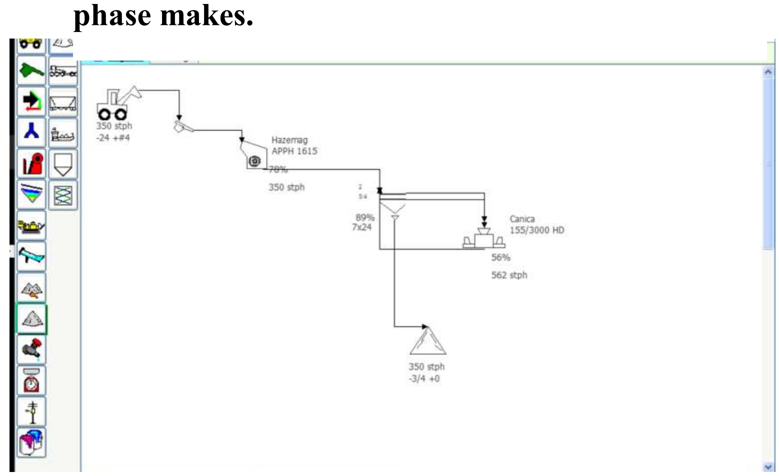


Figure 19 Scenario building software is used to tie in the data and allow for a continuous improvement loop

and gain a bigger advantage (if by better fragmentation at the blast we are able to achieve better raw-mill feed size distribution that will allow to reduce costs significantly)

Managing Stockpile Segregation

In addition to the advantages this technology brings to the pit and crushing operations the drone imaging techniques can capture and present stockpiles fragmentation, assist in understanding the segregation in the pile and mitigating its effect. By separating the stockpile into three distinct zones, operations can use the fragmentation data collected to forecast ideal feed blend and burn rate settings prior to the material entering the kiln.

An example of how drone imaging can be used to improve performance is with the material size in the 'red-zone as seen in figure 8: Now when an operation wants to start pushing outside material through the process, they can optimize kiln settings based on the image analysis data collected.

Figure 20: Stockpile segregation can now be quantified, and the data collected can be used to forecast what material will be feeding the kiln.

CONCLUSIONS

Our ability to attribute fragmentation to a location at the muck-pile allows us to better understand the variables contributing to the outcome. The correlation between the shot parameters, geology and fragmentation helps differentiate between cause and effect and allows an operation to:

1. Set better goals
2. Reproduce what worked well
3. Improve what did not yield expected results

Since the "penny is not always under the light", the more detailed the picture – a fragmentation analysis of each grid block - the better the understanding we have. This will give us a wide spectrum of data. We look for the best result, the worst result and the deviation from our standard. The plant's ideal in-coming material for maximizing both productivity and yield in this case is material above 3/8" and below 12". In cement, the raw mills need a consistent feed (varies based on operation) to reduce standard deviation. The grid location knowledge provides the blaster the ability to relate material size to specific areas in the blast, allowing subsequent blasts to be optimized in line with the operation's goals.

In the case of monitoring the product piles, we work very hard to get the ideal fragmentation curve so we can supply a consistent feed to the mills and the kilns. However, building a stockpile comes with a price; the segregation impacts both the mill and kiln productivity, energy use and product quality. Monitoring the different segregated 'rings' in the pile helps us find the best solution for the consistent feed method by understanding what the segregation looks like and its associated boundaries as it relates to fragmentation.

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- WipWare Incorporated for providing the fragmentation analysis data for this project.

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