Maerz, N. H., 1996. **Image sampling techniques and requirements for automated image analysis of rock fragmentation.** Proceedings of the FRAGBLAST 5 Workshop on Measurement of Blast Fragmentation, Montreal, Quebec, Canada, 23-24 Aug., 1996, pp. 115-120.

Image Sampling Techniques and Requirements for automated image analysis of rock fragmentation

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ABSTRACT: When photographing or video taping rock fragmentation, sampling strategies have to be carefully considered, in order to produce an image that is both capable of being analyzed, and representative of the entire rock assemblage.

A consideration is where the image is to be taken. It could be the top of a muckpile, the front edge or a cross section of the muck pile as it is being mucked. It could be photographed in the back of a haulage truck, the bucket of a loader, or on a conveyor belt. Or it could be photographed in a stockpile. All strategies are valid, but each must be evaluated to ensure good picture quality (i.e. not obscured by dust), and representative sampling (i.e. not skewed because of some size sorting by mechanical processes).

Another consideration is the scale of the image. At the very least, the area must be limited so that the individual blocks can be recognized by the image analysis algorithms. If zoom-merging techniques (images at different scales) are to be used, an appropriate strategy must be employed so that the relative number of images at each scale somewhat reflect the differences in scale. Furthermore, when zooming, care must be taken to avoid pointing the camera at zones of large or small blocks that might attract the eye.

A final consideration is the angle of the surface being photographed with respect to the camera. Ideally the surface should be perpendicular to the direction the camera is pointed, as that eliminates perspective error. Perspective error can also be reduced by using camera lenses with long focal lengths where possible. As an alternative, the image can be rotated (tilted) to compensate for oblique angles. This requires two perpendicular scale bars to be appropriately placed in the image.

1 INTRODUCTION

A universal problem in characterizing large populations with too many individuals to measure is that generalizations have to be made from a limited number of samples (Maerz 1990). In general the more samples there are, the closer the measured sample parameter will be to the true population parameter. If the sampling is not random or systematic, a sampling bias could result in a misleading sample parameter.

In the measurement of rock fragments resulting from blasting (Figure 1) using photoanalysis, both these factors are present. Because of the nature of photography, only the surface of the assemblage is available for sampling. This represents a sampling bias, if the surface is not representative of the whole of the assemblage. Secondly, if the pile is small, relatively few samples can be taken. In addition, economic considerations may limit the number of samples.

2 SAMPLING

To reduce the error in estimating the population parameters, a reasonable sampling strategy must be utilized. In gravel studies, where sieving is used, a common method is to mix a relatively large amount of material uniformly, and use a sample splitter “riffle box” to extract a much smaller amount for sieving (ASTM, 1972). The sample splitter ensures that the small sample to be measured is representative of the larger population. This strategy clearly cannot be used routinely for large sized blasted material.

2.1 Photographic sampling

Typically, a muck pile is heterogeneous with respect to fragment size. Depending on the blast design, the largest sizes could be thrown the furthest from the blast, or they could slump down directly next to the blast. There may be some sort of gravitational

Figure 1. Blasting sequence producing fragmentation.

segregation, where the fines are covering the larger blocks or alternatively the fines may have slipped in and behind the larger blocks, for example in quarries exposed to wind and rain.

2.2 Sampling Location

If the assumption is made that the surface of a muck pile is representative, sampling can be simply a matter of photographing the surface.

There are however many alternatives (Figure 2). If the assumption of a representative surface cannot be made, the alternative might be to create one or more vertical cuts through the muckpile during the normal mucking operations. This strategy however can introduce delays in the mucking operations. Additionally, the fragmentation in vertical cuts can be obscured by dust sloughing off the surface.

Sampling could also be done during the material handling process, in the backs of the haulage trucks, or in buckets of loader, or on conveyor belts. This allows photographic sampling of a surface which is created during the loading phase rather than by other processes. This surface could be much more representative of the assemblage in the truck because it is in effect mixed when it is loaded.

Finally, sampling can also be done on the surface of stockpiles.

2.3 Sampling Strategy

A sampling strategy must be employed to avoid systematic sampling biases. Without a clear strategy, a personal bias enters into the picture. Some photographers will be drawn to the largest particles; others will select areas of uniform distribution.

There are really only two sampling methods available; random, and systematic. In both cases decisions about sampling locations are made before going into the field and viewing the fragmentation. In both cases the fragmentation surface is divided up into manageable sections, and decisions are made as to which sections will be sampled. In both cases there are constraints based on the geometry of the layout with respect to the objective distance and angle to potential camera positions.

Random sampling involves picking one or more of these sections using statistical methods (Cochran, 1977).

Systematic sampling involves either sampling the entire fragmentation surface, or a subset of the entire surface, based on a systematic grid covering the surface.

Random sampling is best when the number of images that would be required to cover the fragmentation surface would overwhelm the capabilities of the image analysis system. Systematic sampling on the other hand, gives greater assurance that spatial variations in size are taken into account.

A simple example of a systematic sampling strategy for a muckpile (local regulations permitting) is as follows. Sampling points can be pre-selected (perhaps marked by spray paint) on the top of the muckpile along the centerline of the muckpile, each at an increasing distance along that line. At each sampling point an image is taken either of the surface of the muckpile, or of the muck in the bucket of a loader, or in the back of a haulage truck. The operator of the loader can be asked to lift a complete vertical section into the haulage truck, to remove any vertical variability.

Figure 2a. Fragmentation: Top: Surface of muckpile; Middle: Vertical cut in muckpile; Bottom: Stockpile.

An advantage of this method is that many samples (replicates) can be taken, thus allowing a measure of the variability of the method. The disadvantage of this method is that it is time consuming. The photographer must be present during the entire mucking operation, and small delays in the mucking operation can be expected. The complexity of the sampling strategy must consider the purpose of the investigation: Simple for routine work, more complex for research applications.

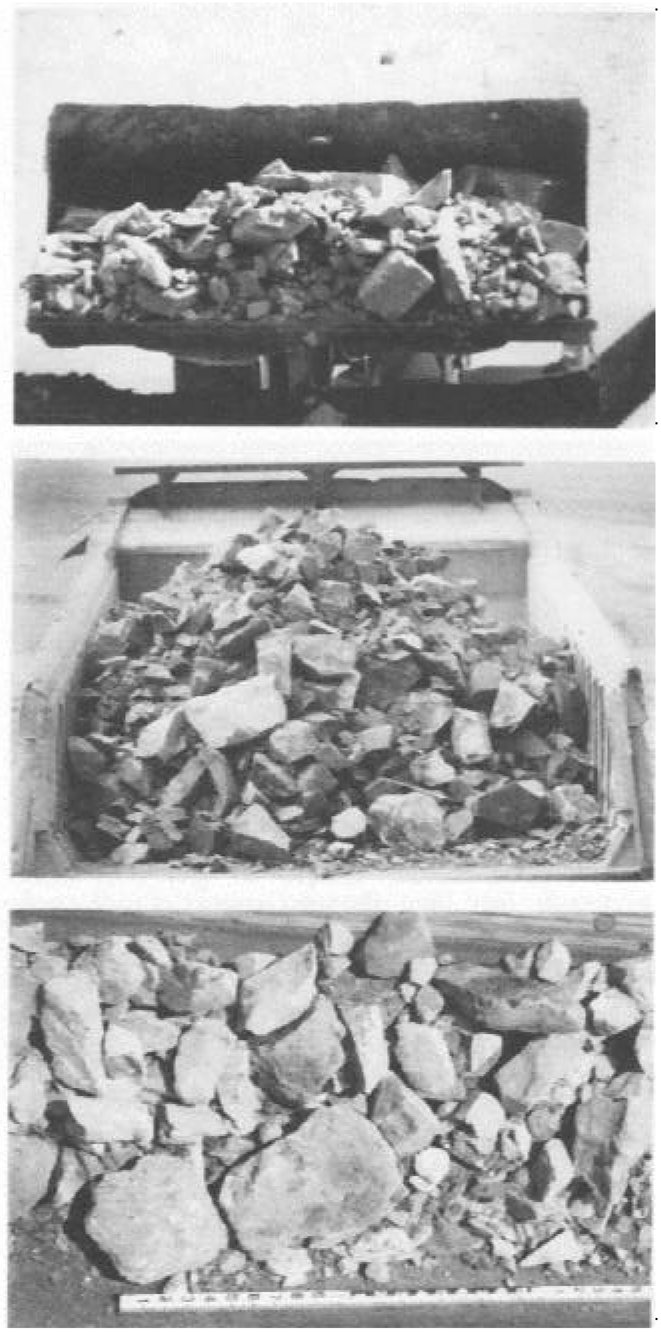

Figure 2b. Fragmentation: Top: Loader bucket; Middle: Back of haulage truck; Bottom: Conveyer belt.

3 IMAGE QUALITY

3.1 Resolution

For every imaging/image processing system, for each given image, there is an effective minimum block size that can be resolved and delineated. Thus individual images to be used for processing must meet that minimum resolution.

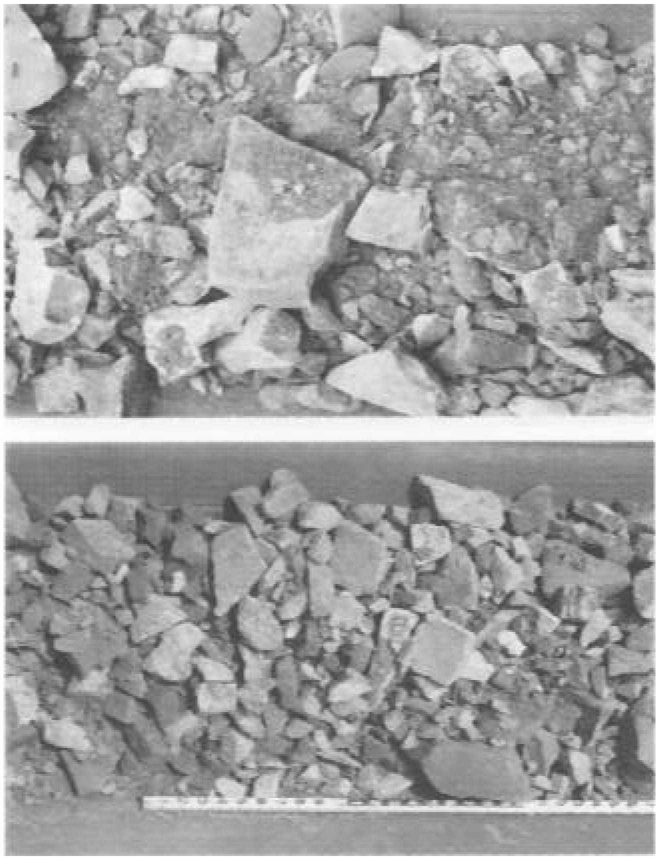

Figure 3. Top: Dust obscured sample of rock on the conveyor belt; Bottom: Dust free sample of rock .

Clearly, resolution can improved simply by zooming in closer (Section 4.3). As such there are no theoretical limits to the resolution of an analysis.

3.2 Lighting

Proper lighting is essential for automated edge detection of rock fragments. This includes both intensity, uniformity, and contrast.

Of the above three parameters, light intensity is the least significant, unless it has a direct bearing on one of the other two. Most imaging systems have the ability to compensate for low intensity lighting.

Lighting uniformity is most critical in underground applications, where the source of light is typical a single spot lamp. Here the image is typically brightly illuminated at its center, with intensity falloff toward the edges. While image processing techniques can minimize the effects of intensity falloff to some extent, better results are obtained with images of more uniform lighting. When using natural light above ground, this is usually not an issue.

Finally, the contrast in the image must be appropriate. Most image analysis systems use the contrast between the relatively lighter colored blocks and the relatively darker colored shadows between the blocks.

If the contrast is too high, the resulting textures on the block surfaces will be misinterpreted and single large blocks will appear to be broken up into numerous smaller blocks (Franklin and Eden, 1996).

If on the other hand the contrast is too low, the shadows between blocks will be lost, and numerous smaller blocks will appear to form a single larger block.

In underground situations (artificial lighting), poor lighting may result in excessively high contrasts. In above ground situations (natural lighting), low angle bright sunlight can result in high contrast, while diffuse lighting from heavily overcast skies can result in low contrast.

3.3 Dust

While a significant problem in the blasting industry, dust does not normally constitute a significant part of the bulk of a muck pile. It does however create problems for image analysis systems.

Dust has much too fine a grain size to be efficiently and accurately measured by image analysis systems, and when present, tends to confuse the edge detection algorithms.

Figure 3 shows two views of a conveyor belt, one obstructed by dust and the other relatively clear of dust. In the first case, most image analysis systems would misinterpret the zones of dust as large blocks.

4 SCALE OF SAMPLING

4.1 Single Image Analysis

The scale of sampling, i.e. the size of the image can also be thought imparting a sampling bias. Depending on the scale of observation, there are three categories of blocks which may not be sampled, because they are not visible in the photograph:

1. Large blocks, in images of small surface area, may for example not have been loaded because they are too large to fit into the loader bucket.
2. Small blocks may not be visible because they are too small to be resolved on the image.
3. Small blocks may not be visible because they have fallen in behind larger blocks.

Clearly the scale of observation in a single image affects measurement results.

For a given size and resolution of image, there is a sampling window. Outside of this window there may be blocks too large to be included and blocks too small to be resolved. As the sampling window is increased in size, less small fragments and more large ones will be measured, and the measured average size increases.

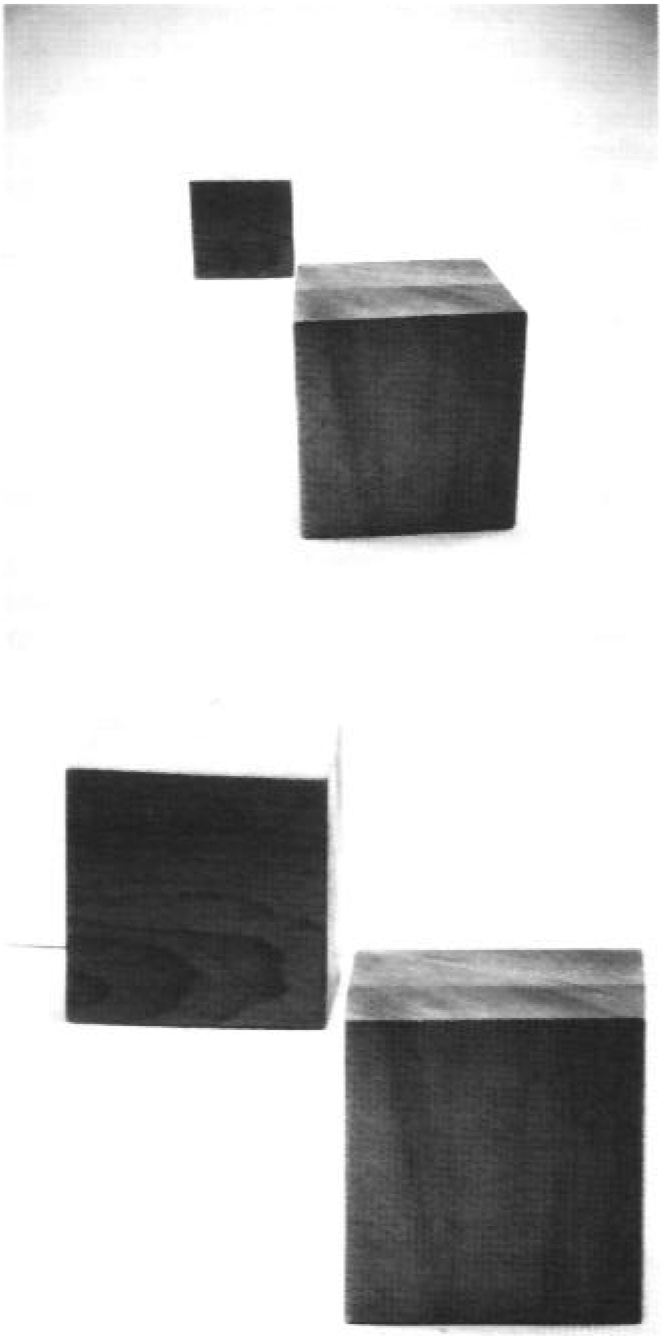

Figure 4. Top: Two identically size blocks photographed with a wide angle lens, and Bottom: The same two blocks in the same position photographed by a telephoto lens.

The problem is however easily bounded at one end: The largest sizes can be identified, and the sampling window can be scaled to include the largest sizes. The other end however is not so clearly bounded. Block sizes range down to the size of fine dust. As the sampling window is scaled down, and as more fine sizes are resolved (assuming they are not hidden), the measured average size decreases.

For this reason, multiple image analyses (at different sampling scales) should be used when greater accuracy is required.

4.2 Multiple Image Analysis (Merge)

Using multiple images (at the same scale of observation) and merging the data into a single analysis results in much greater accuracy. This is a result of increasing the number of blocks sampled, without increasing the size of the sampling window, as would be the result of sampling more blocks (imaging a larger surface area) in a single image.

The sampling window for images at a single scale of observation results in a measurable fragment size range between 1 and 1.5 orders of magnitude. To expand this range, zoom-merge techniques need to be used.

4.3 Multiple Image Analysis (Zoom Merge)

Limited resolution is one of the main sources of error in image analysis, and depends entirely on the fragment size relative to the image. On a single image, a group of particles too small to be resolved may be “fused” together and be identified as a single larger blo ck, thereby increasing the measurement bias toward the larger sizes.

Analyzing images acquired at two or more different scales (zooming in, and merging the data files) is a way to expand the sampling window (Santamarina, et. al., 1995). In this way more accurate results can be obtained, however at the expense of a more involved and more time consuming analysis.

At the scale of extreme fines (e.g. dust), this is only a partial solution, as the zooming in would not sample the fines which are not visible in the image because they have fallen in between and behind the larger blocks.

5 PERSPECTIVE ERRORS

Best measurements clearly result from images taken at right angles to the surface being measured. This is however not always practical. For example, the surface of muckpiles are normally fairly horizontal, and it is often difficult to get an orthogonal view.

5.1 Telephoto Photography

Given that images may at times be taken at oblique angles, an excellent way to minimize the distortion is to use telephoto lenses (Figure 4). The use of “long” lenses tends to flatten out the image, minimizing the measurement errors.

Telephoto photography however is not always possible, for example in an underground drift, where the quarters are to tight to stand back at the appropriate distance.

5.2 Rotation (Tilting of Images)

Alternatively, the perspective error can be removed by "rotating" or "tilting" the image during the analysis phase.

This approach requires knowledge of the angle between the view of the camera and the tilted surface, or alternatively requires two scaling objects in the field of view to define that angle.

6 SPECIFICATIONS

Some basic specifications for photographic sampling are as follow:

The camera should be positioned normal to the surface being sampled, to avoid the perspective error of having closer blocks appear larger than those further away.

A telephoto lens should be used where possible. This flattens and compresses the depth of the image, and minimizes the perspective error.

Some indication of scale must be photographed. This could be anything from a scale bar placed in the foreground (preferably along one edge of the image), to a natural part of the scene with known dimensions, such as the box of a truck.

The area of coverage of a single image should be calculated. If too few fragments are photographed, the results may by statistically erratic. If too many fragments are photographed, the image analysis system may have difficulty in identifying individual blocks and smaller fragments will be lost because of the spatial resolution constraints of the system. A general rule of thumb is to sample at least 400 visible fragments, and preferably between 500 and 1500 fragments per image. The largest block in the image should occupy no more than 20% of the image.

The location of the sample or samples should be determined consistent with some valid sampling strategy.

Comprehensive specifications for the case of the WipFrag system are given in Palangio (1996).

7 CONCLUSIONS

Automated image analysis an extremely useful tool in analyzing block size of blast fragmentation. The results of the analysis however reflect only the size distributions of the blocks in the actual image or images being used. It is therefore up to the operator of the system to develop an appropriate photographic sampling strategy, to avoid systematic biases and errors. This involves the following:

1. Selecting an appropriate sampling location.

2. Imaging at the appropriate scale or scales of observation, using zoom merging techniques if necessary.

3. Minimizing perspective errors, by imaging at near right angles to the rock surface to be measured, or using telephoto lenses to flatten the image, or by doing a tilt (rotational) correction to the image using software.

4. Producing images of sufficient clarity and lighting, so that they are capable of being analyzed..

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