Comments on Rock blasting

Flyrock (part 02 of 03)

By Bruno Pimentel.

Hello my friends, I hope you are enjoying our Newsletter on rock blasting, and for those who are just arriving, I invite you to subscribe through the links below, and of course, do not forget to check out the previous articles:

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As we commented in our last article, we will be continuing with the **Flyrocks** theme, which is without a doubt one of the biggest concerns when performing blasts in the open pit, and as we commented, historically is responsible for approximately 30% of accidents related to this activity.

There are several factors that can generate flyrocks, but most events are related to the punctual “escape” of the gases generated by the explosive, which, seeking a path of least resistance, push everything and everyone in front of them, and this makes with that sometimes fragments are launched at greater distances than the standard launch of the material, and when this distance exceeds the clearance zone, we have a flyrock event.

Cratering | Face burst | Rifling

Generally, the factors generated from flyrocks are linked to some condition of our blasting, which may be characteristic of the rock block to be blasted, or even a condition created by the operational practices in the blast, so it is our role to avoid the creation of these operational conditions. and identify the intrinsic conditions, so that we can take appropriate preventive measures.

So in today's article, we are going to dedicate to commenting on the main factors and conditions that we need to be aware of in any blast, because as we said, there is no magic technique that eliminates the risk of flyrocks, and no matter how controlled our blast is, the best alternative is to prevent, through the identification of risk situations and the implementation of adequate control measures for these situations.

- **Natural conditions**

As simple as it may seem, one of the most uncontrollable factors is the natural conditions that can affect our blast, such as the presence of water, especially dynamic water, which can contribute to the creation of weakness points in the rock or create paths for the escape of the gases, in the same way that even rain can cause water to soak into the rock, reduce the efficiency of stemming, or even migrate through fractures, removing the friable filling material. It can still mask bench conditions, making it difficult to assess and perceive other risks.

In the same way that the presence of lightning and storms can cause premature blasts and thus generate unexpected flyrocks.

The wind can also contribute to the intensification of flyrocks, as it is believed that when the wind direction is in accordance with the direction of release, it is estimated that the flyrock can travel a distance of up to twice as long as normal.

So even though it is impossible to control these conditions, and that in most blasts they represent minimal interference, it is important to be aware of the possibility of these risks, anticipating a forecast of heavy rain or electrical discharges, or even leaving a preparation suitable, because anyone who, overnight, has found the blast area completely submerged, with detonator cables floating and holes missing, knows well how unpredictable these situations are.

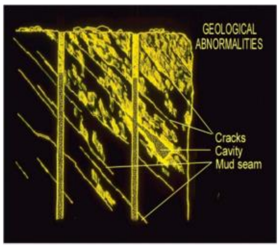
- **Rock geology**

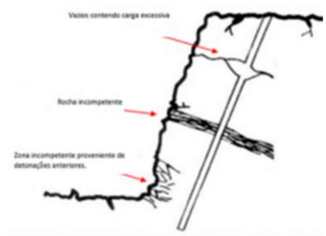
One of the major difficulties in rock blasting is the lack of knowledge and effective technologies to identify and recognize anomalies or weaknesses present in rocks. So happy will be the day when we have a scanner linked to probing technologies, which can make a complete reading of the rock, indicating its internal characteristics, because in many blasts, these characteristics seem to be one of the greatest mysteries of the universe.

It is important to be aware, because the properties and structures of the rock can vary considerably in the same blast, and especially along the blasts carried out in a rocky mass, and there are several conditions that can contribute to the generation of flyrocks.

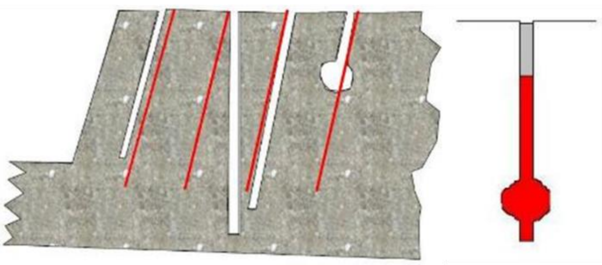
Sudden changes in rock types and structures can cause a mismatch between explosive energy and rock strength. It is prudent to try to detect such changes in advance and adjust the design parameters.

Discontinuities and differences in structure can cause a difference between the energy of the explosive and the strength of the rock. In the same way that changes in compressive strength, variation in abrasiveness and rock density can also generate worrying scenarios.

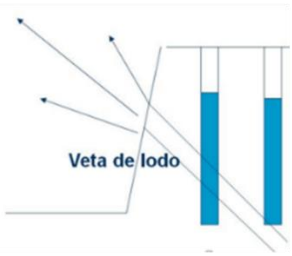


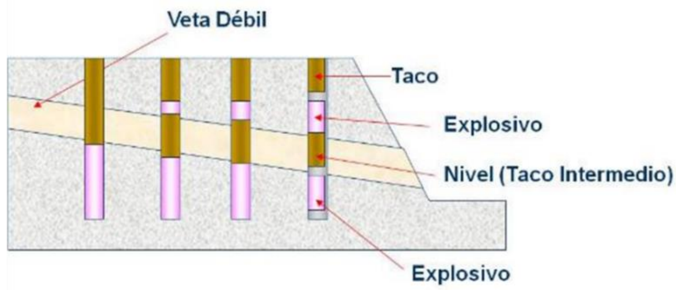


In the case of the presence of cavities and cracks in the rock, these can be filled with a greater amount of explosive during loading, which can increase the concentration of energy causing a greater launch and a great potential for the generation of flyrocks at greater distances.

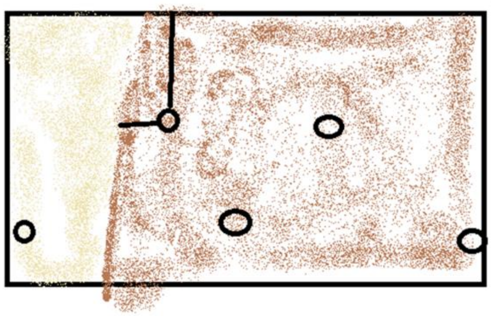


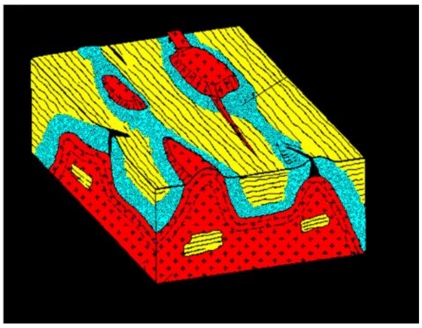
Geological features such as fill material, joints, fault planes or cavities in the rock can produce points of weakness, which facilitate the escape of gases during the blast.



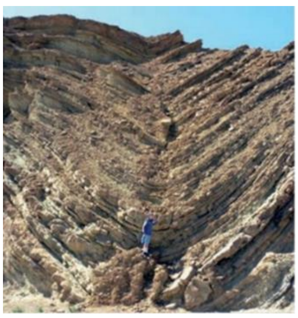


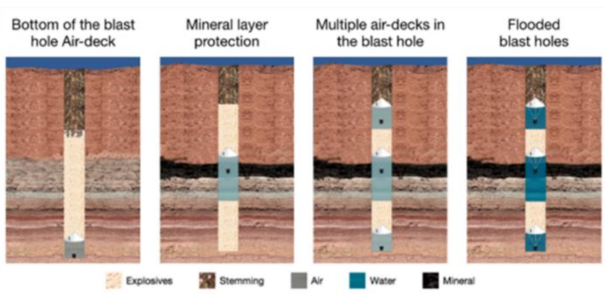
Another critical condition is when we have contact regions, between rocks of different characteristics in the same blast, where for example, a hole in a hard rock, which is closer to a contact region, can use it as an alternative free face, due to lower resistance.



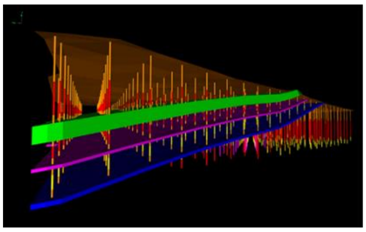
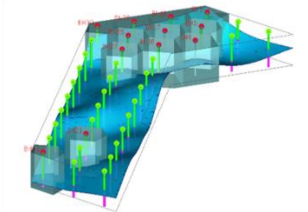
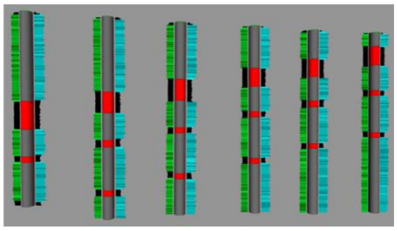


Sedimentary rocks often change their geomechanical properties due to sudden changes in the lamellar direction and/or bedding planes. Geological intrusions can compromise the strength of the base rock.





We cannot forget that geology plays a fundamental role in the planning of a blast, and so the identification of possible anomalies is an imperative need, both to guarantee a good result and to guarantee the safety of our blasts.

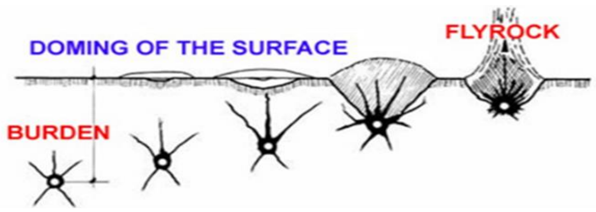




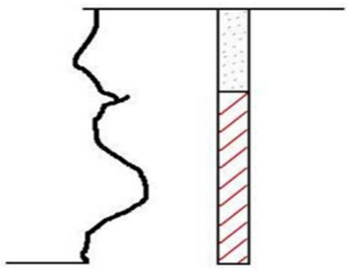
• Inadequate burden

The standard burden is defined as the distance between two rows of holes, but in practice we can consider it to be the shortest distance between the hole and the free face, and it plays a fundamental role in the general release of the blasted material and in the containment of the energy of the explosive during the fragmentation process, and therefore, a good design and control of the real burden in the blasts, is indispensable to minimize the risk of flyrocks.

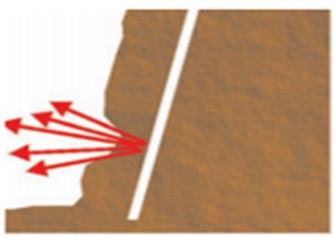
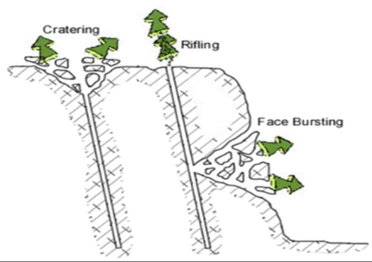
There are several situations that can cause a hole to have a critical burden, mainly due to irregularities in the face of the bench, making it a challenge to control the actual burden of each hole. But fundamental attention is important, especially with the first line holes, as short burdens will generate a punctual release of energy, and are usually one of the main factors that generate flyrocks.

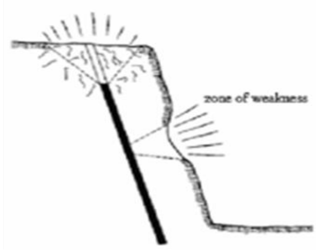
To avoid irregularities related to the burden of the front row it is important to ensure that the holes are correctly allocated with respect to overbreaks/inclination of the free face and also to control the mining/cleaning along the free face.



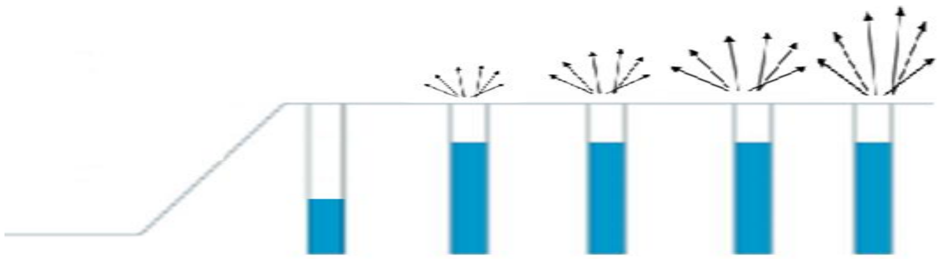


A universal rule of thumb should be to plan each hole in the first row independently and then adjust the others. The loading in each hole must be a consequence of observations regarding the face conditions. If you suspect that any area has insufficient/small burden, take action to make some modification to your load to compensate. Use explosives with less energy or use decoupled charges (cartridges), or use intermediate/step stemmings in the holes.

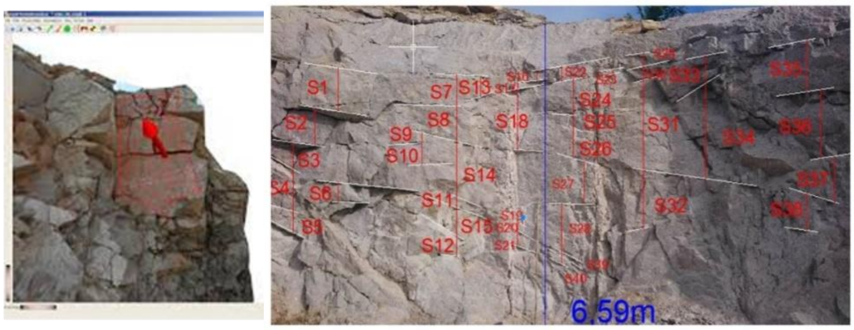


In the same way that very short burdens provide points of weakness and can cause a punctual release of energy, very large burdens have a tendency to create blocks and result in sharp vertical ejections, which can also contribute to the generation of flyrocks. In the same way that blasts with many lines can create a cascading effect, intensifying the ejections, and this is especially true when we do not have adequate sequencing, which is another factor that directly influences the real burden of our blast.



- **Overbreaks**

A specific situation is the overbreaks generated by the previous blasts, which despite not being a natural condition of the rock, can create a risky scenario for the next blasts, and it is often an unknown situation during the blast plan design, because the face may still be covered with material, which is still being extracted while the next blast is already being prepared, and therefore, a good evaluation of the free face, is a point that must be checked carefully before performing any blast.



- **Inadequate drilling**

There are five main drilling errors that can influence and increase the possibilities of flyrocks, namely:

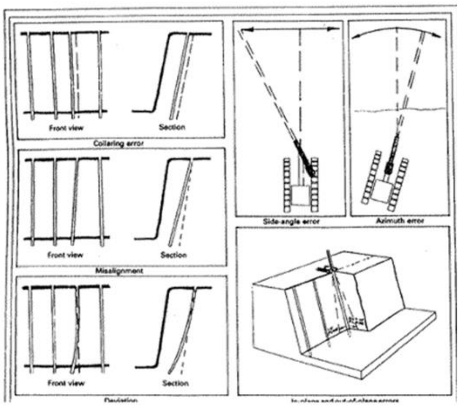
Placement/Entrance = Error of topographic location X and Y of the mouth (collar) of the hole compared to the planned.

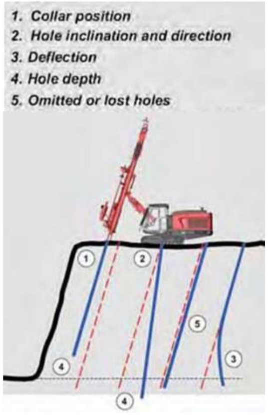
Inclination = Error in the angle of the hole compared to the theoretical one.

Orientation = Error in drilling direction, determined by the free face.

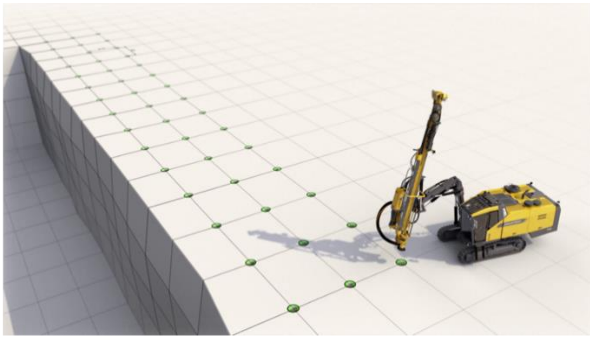
Deviation = Error caused by deviation during drilling, due to changes in rock or equipment (soft rod, poorly connected, etc).

Dimensioning = Error referring to depth and diameter measurements different from the dimensioned one.

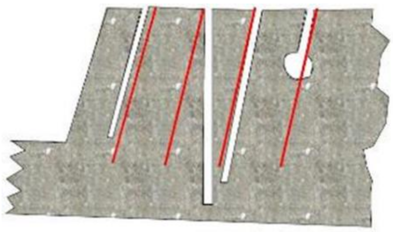


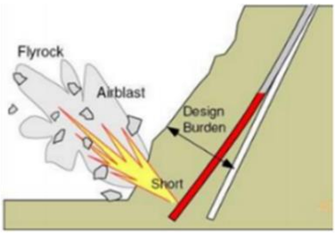


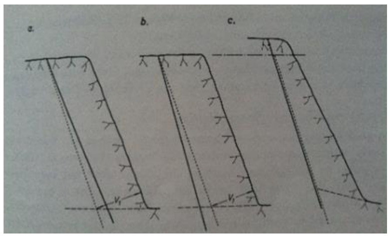
Positioning errors can join or separate holes in a plane, in the first causing a concentration of charge and in the second increasing the amount of rock/resistance.



In addition to positioning, errors in inclination and direction are another big problem that can contribute to the occurrence of flyrocks.

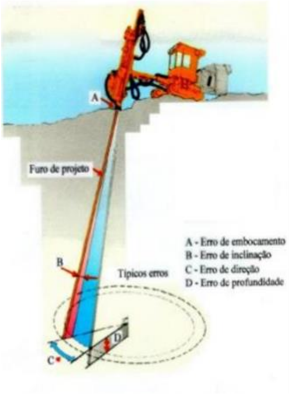


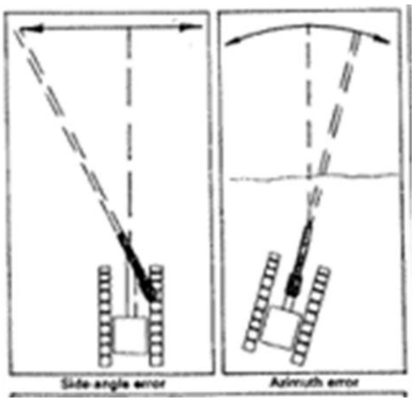


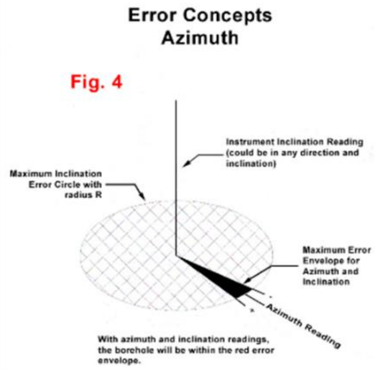


When using angled drilling, all holes must be directed to the free face/launch direction/material output. Guidance errors are common when there are more than one machine or different operators on the same drilling site, if this is not well marked physically in the field or in the equipment's navigation system.

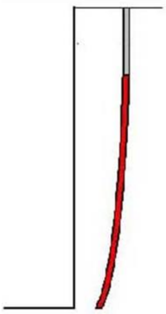
Orientation errors can make it difficult to launch the material, causing resistance to the other holes and boosting the vertical launch of the fragments.

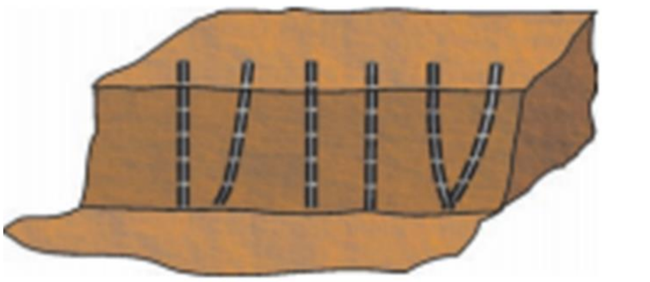


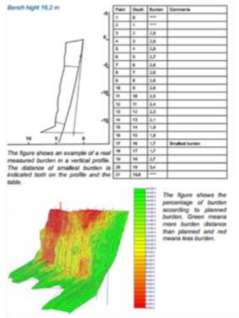




Two critical situations are when we have a deviation reducing the real burden of the hole, mainly in the first line, or when two holes are approaching, causing a concentration of energy that will result in greater launches.



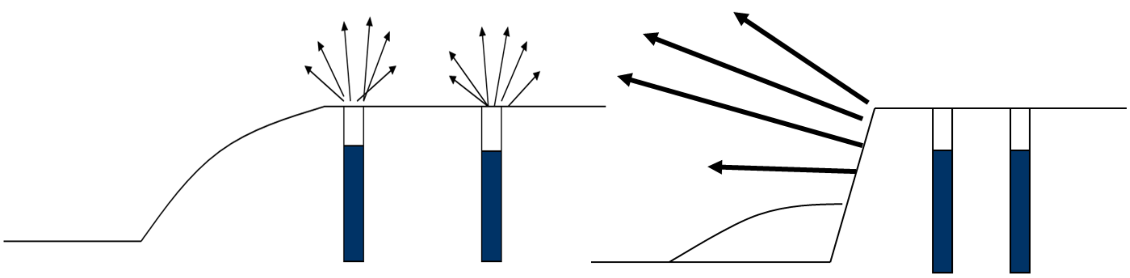




- **Material deposited on the free face**

A common situation in many operations is the preparation or excussion of the blast, with material from previous blasts still on the free face, and this has two consequences, the first is the impossibility of an adequate evaluation of the free face, preventing the correct sizing. of the holes in the first line, and the second is that the weight of the material will decrease the relief needed for the blast, causing an increase in ejections.

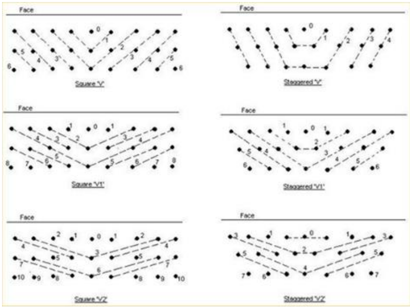
But we also have to be careful with the reverse situation, where excessive excavation is carried out, sometimes due to material weakness or overbreaks of the previous blast, causing a reduction in the burden of the first line holes.

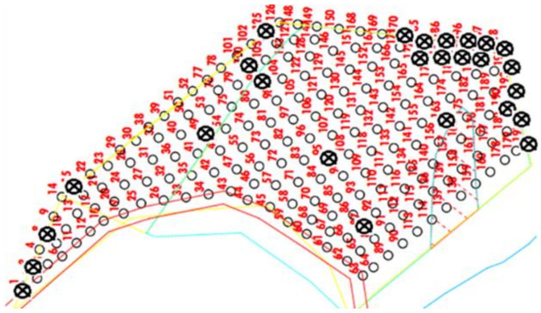


- **Holes blocked/not loaded**

Another situation that can increase ejections or alter the material output sequencing is the presence of blocked or missing holes.

Blocked holes can still serve as gas escape points, especially in more fractured rocks, and the very fragments that are blocking the holes can be thrown out undesired.

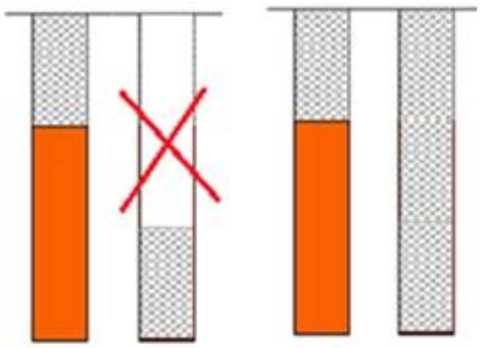




In operations with critical conditions, it is common to need to repass some holes that are blocked during the drilling or loading process, when it is not possible to recover these holes, it is common practice to drill new holes nearby to replace the blocked ones. In these cases, special care must be taken with the unusable holes, as they can serve as an unwanted free face, generating points of weakness for the escape of gases.

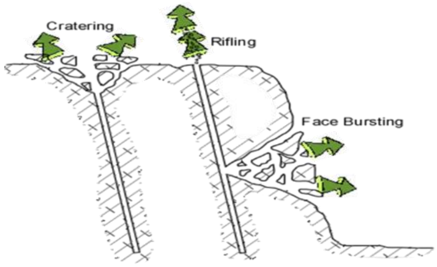
These holes must be closed completely to minimize the escape of gases. The amount present must be carefully evaluated, because if it is a generalized condition, extra preventive measures must be taken, such as reducing the load or increasing the clearanze zone.

Attention should also be paid to drilling holes, previously made for pre-mining research, as they can generate this same unfavorable condition.

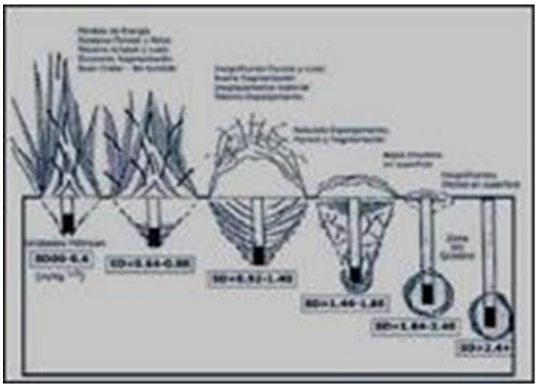


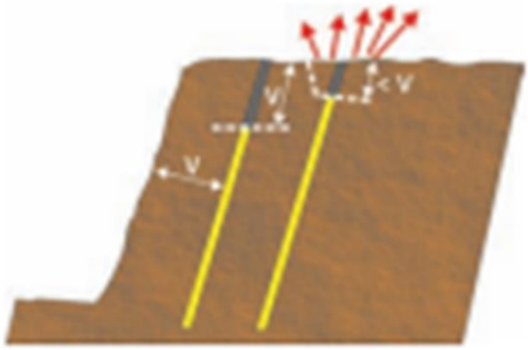
• Inappropriate stemming

Stemming is responsible for providing containment and preventing high pressure gases from escaping during the blast of each hole. Ideally, the stemming should present a resistance to the exhaust of the cases equivalent to the resistance presented by the burden, otherwise it will serve as an escape point for the gases.

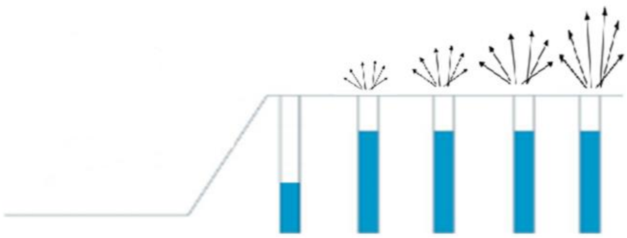


The blast gases always go through the easiest path, which is usually through the stemming region, as the stemming material is already fragmented, this causes energy loss and less pressure on the walls of the hole, generating insufficient material movement and increasing even more ejection.





It is often misunderstood to assume that a very large stemming in the front row holes solves all associated flyrock problems. An inadequate displacement of the holes in the first line, due to a low load of these holes, will cause a ripple effect of this reaction to the other lines, thus increasing the ejections and probabilities of flyrocks.



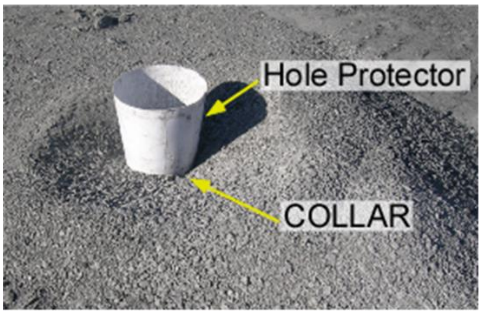
The quality of the stemming material is another key factor in preventing flyrocks from occurring. When we have a poor stemming quality, either because it is insufficient or the material is unsuitable, it does not have enough strength to stop the escape of the gases released in the blast.

From the beginning of the operation, an exhaustive control of the stemming must be carried out and immediate measures must be taken if it is smaller than the design length. The error in stemming should always be for more and never for less.

Whenever necessary, it is recommended to use a phase separator, such as plastic or a plug, to prevent the stemming material from descending into the explosive column, causing it to rise and reduce the final length, as this may contribute to the increase in ejections.

When there is water present in the stemming, it works as a lubricating fluid, decreasing the adhesion of the material and, in turn, the confinement capacity.

Whenever possible, the use of detonating cord inside the hole should be avoided, as it either in the top-down or bottom-up blast opens an escape route for the gases through the stemming.



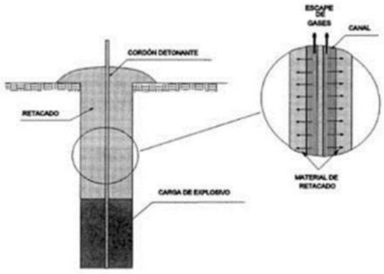
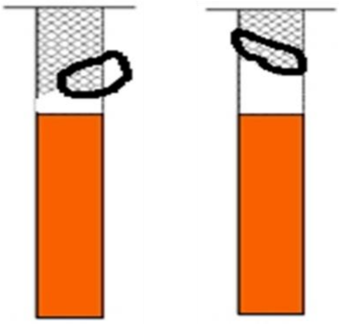


Figura 28.7. *Creación por el cordón detonante de una vía de escape de los gases a través del retacado.*

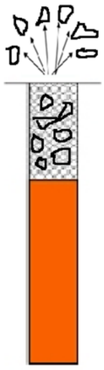
- **Obstruction of stemming**

During stemming, loose fragments in the square, in the hole top or mixed with gravel can cause a partial or total obstruction of the stemming, this can imply a deficiency in the confinement capacity, in addition to leaving a void indicating an initial direction for the escape of the gases.



- **Cannon effect**

Stemming is responsible for promoting confinement and preventing the escape of gases released by the blast of explosives, so it must be well executed and its material must be as suitable as possible, always free from larger fragments.

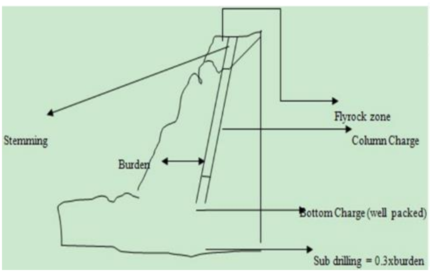


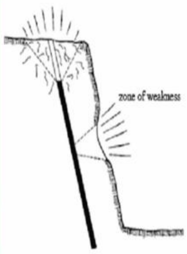
These larger fragments can cause disproportionality in the adhesion between the material used in the tamponade, a factor that can contribute to the increase in ejection.

Due to their greater surface area, these larger fragments can suffer a "cannon effect", being thrown like projectiles over long distances.

- **Loose material**

It is already common for the top area of the bench to have irregularities due to blast from the upper floor, but in addition, it is common to leave a layer of lining material, either to better level the square or because adequate cleaning was not carried out, and depending on the intensity of these irregularities and the amount of material, as well as the characteristics of stemming, we can have an increase in the ejection of material, as well as loose fragments can be easily released due to strong ejections or escape of gases, and these scenarios need to be properly evaluated. , as they can span the entire length of the blast and can be a difficult scenario to identify due to the compaction of this material.





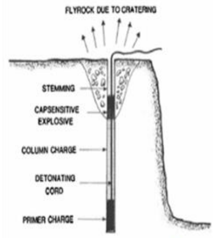
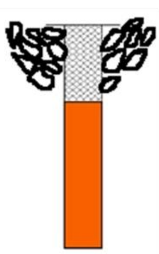


Fig. 1 Large burden and top priming causes flyrock [29]

- **Loose fragments in the hole mouth**

As mentioned, it is common for the upper bench blast to cause damage to the top of the lower bench, this due to drilling irregularities, sub-drilling errors, excess load, and other factors, causing a favorable condition for the escape of gases during the blast. This weakness in the mouth of the holes may imply a possible reduction in the gas confinement capacity, generating an escape point and causing an increase in ejections.

In these conditions, several loose fragments are around the mouth of the holes, which can be released by the gases generating flyrocks and unwanted consequences. Before loading, it is necessary to clean and remove these fragments to prevent them from falling blocking the hole or being released during the blast.



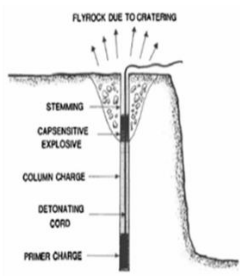


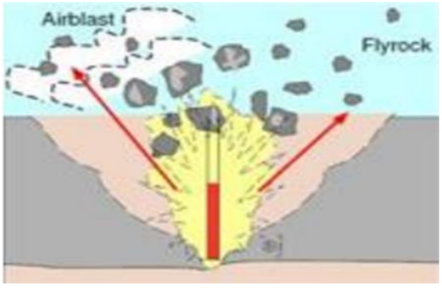
Fig. 1 Large burden and top priming causes flyrock [29]

- **Large diameter holes >8"**

In large diameter holes it is always necessary to have control of the amount of charge that is placed in it, as any variation can represent a large amount of extra explosive. Depending on the diameter and depth of the holes may contain more than 1 ton of explosive present.

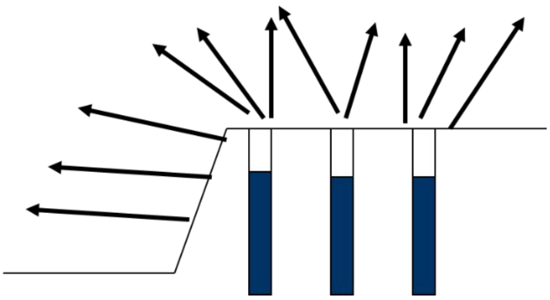
Another point is that the larger the diameter, the lower the ability of the stemming to stick to the wall of the hole, thus generating a weaker confinement, requiring a longer stemming length to compensate.

If the relationship between stemming height and hole diameter is too small, we may have a greater ejection of material and fragments may be projected in any direction.



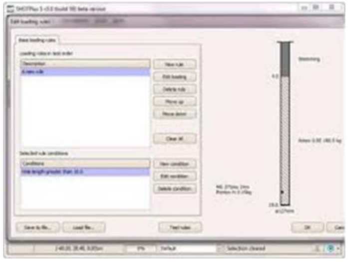
- **Excessive energy concentration**

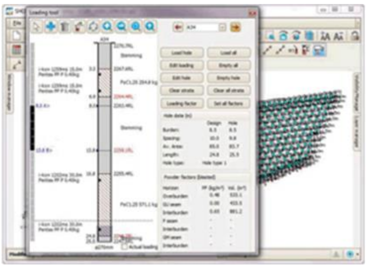
High power factor is one of the most frequent causes of flyrocks. The amount of explosive can be changed by a number of factors during loading, such as rock conditions, voids, human errors, etc.



Lack of design, operational errors, lack of truck calibration, inadequate measurement, lack of monitoring, etc., are some of the factors that can cause loading errors, causing overload and a high probability of generating flyrocks. That is why it is always necessary to carry out an evaluation and follow-up throughout the loading process, being necessary to have control over the amount of explosive in each hole, and the way in which the explosive is applied. A basic rule is that you should never exceed more than 10% of the total planned load, without having a controlled justification for doing so.

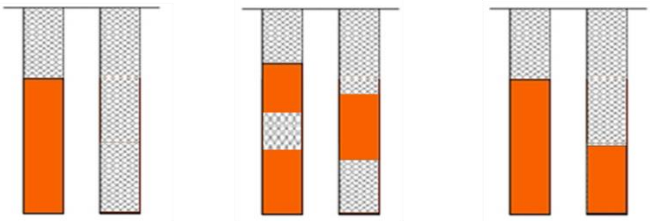
Although we make a loading plan for the entire blast, the actual loading of each hole must be a consequence of its measurements, deviations and characteristics.





- **Nearby holes**

Due to lack of plan, positioning errors, etc, there may be a condition in which two holes are very close to each other. These holes need to be carefully evaluated, one of them should not be loaded (in this case, it should be completely plugged) or the load should be reduced considerably in one of them. Never normally load two holes that have spacings or burdens less than 70% of the design measurements.

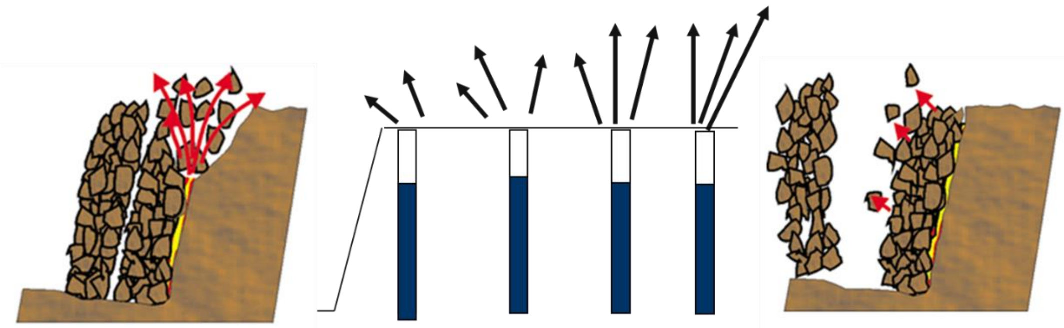


- **Inappropriate delas**

It is important to determine the right delay times on a blast. Each hole or line should act as a protective cover for the hole that will be blasted next, but should not trap it any further than necessary.

If you have very short delays between rows, the load on the back row will force the fragments to come out on top, as the front ones haven't come out yet to free up space and this will get worse in the other rows. This effect can generate vertical flyrocks.

If you have very long delays between lines, the front line will not serve as protection. So the second row will act as the first and at that point you will have no control over the burden, and the same will happen for all the other lines.

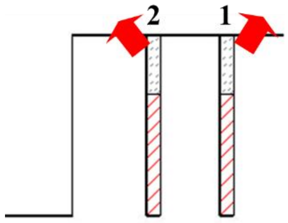


- **Inappropriate sequence**

The sequencing of a blast has several functions that will impact practically all the characteristics of the results obtained, from fragmentation to the preservation of the blast surroundings.

In the same way that the sequencing directly influences the release of the material, and that a bad sizing or errors can be factors that generate flyrock.

Proper sequencing will control material release and direction and will produce the proper level of relief throughout the blast to reduce ejections. While errors in the design or execution of the sequencing will affect the entire result, as well as the impacts generated by the blast.



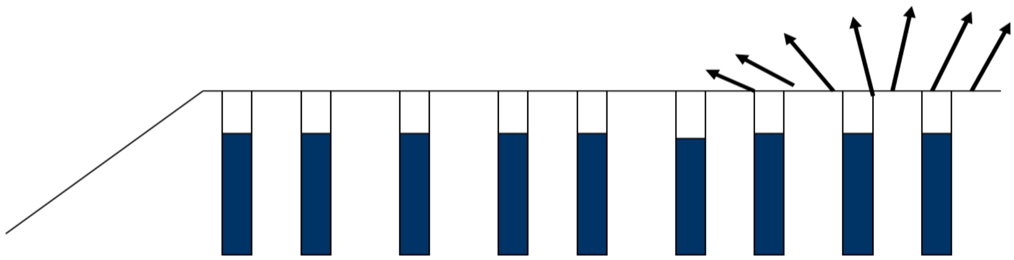
- **Blast shape**

Another point that can affect the performance of our blasts is the shape of the rock body to be blasted, both in terms of its geometry and dimensioning.

When performing long blasts, with many lines, special attention should be paid to generating relief. Each line will have its face reduced by the launch of the front line, reaching a point where its face will be completely filled with material, generating an over confinement and boosting the vertical movement. The time between lines must be increased to allow the greatest possible relief and in some cases the stemming must be gradually increased.

In very narrow blasts, there is a certain limitation of the face, mainly for the lateral holes. It is necessary to evaluate the relief of each hole and increase the plugs in the holes with less face.

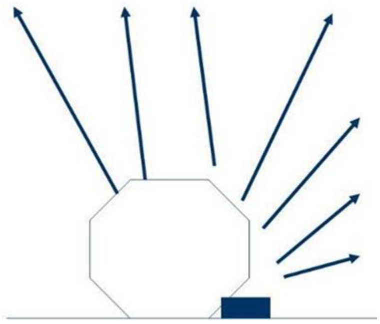
You should avoid drawings in which holes are stuck or scattered, as these may not follow the movement of the material, in the same way that very irregular contours can make it difficult to adapt the drill pattern and the holes, creating points that are difficult to dimension.



- **“Special” blasts**

In addition to production blasting, which is the daily routine of most mining companies, there are a number of other types of blasting that require special attention, due to their peculiar characteristics and less predictability of their result.

- ✓ Regularization
- ✓ Lifting holes
- ✓ Failed hole
- ✓ Blocks
- ✓ Pre-cut
- ✓ Sump/level opening
- ✓ Opening ditches, trenches, etc.
- ✓ Others



All these examples and others, bring adverse conditions different from the standard blast conditions, where it is often not so easy to find the balance between the parameters of our blast, and in the same way that we can have specific situations, such as secondary blasts, where the rocks have already been shaken by a first blast, and thus no longer have the same resistance characteristics, or level opening blasts, which have an excessive confinement that naturally already causes greater ejections.

An extremely critical situation that presents a high risk is when we need to detonate failed holes, as both the explosive and the characteristics of the holes are often unknown, due to the damage suffered during the blast.

In most of these cases, additional controls are needed, such as increasing the clearanze zone, increasing stemming when it exists, performing forced smothering with friable material or blankets/belts, etc.

- **Human Error**

To finish our article, as they seem to get longer and longer, the point of greatest concern in carrying out blasts, and which affects control over all possible impacts, is the human factor.

Human error is one of the factors that is always present in investigations of accidents with rock blasting and especially with regard to flyrocks, both in terms of carrying out inadequate practices and in terms of failure to carry out the due controls.

The prevention of flyrocks must be managed proactively, including the identification and analysis of precursor events. All necessary and relevant measures must be taken to prevent and avoid systematic errors and inadequate work practices that could result in accidents.

We need to understand that the preparation and execution of the blast is performed by people, and that people usually make a lot of mistakes, intentional or not. Therefore, adequate training, constant supervision and the establishment of redundant controls are essential to increase the security level of our operations.

We have several people involved, from the design to the execution of the blast, and each one of them needs to do their part and in the same way contribute to the other to do theirs in the best possible way. For example, the drill operator can alert the blaster of identified anomalies in the drill, the helper can alert the blaster of abnormal behavior during loading, and so, in addition to ensuring our share of responsibility, we help the assembly to do the same. .

Failure to understand instructions or transmit information is another key point of how communication errors affect the performance of any operation. Consistent and timely information should be one of the strengths of any good operation.

The need to follow what was designed and that every change made needs to be recorded and shared with the entire team is an imperative factor in preventing flyrocks.

Oversights with checking the perforation and final stemming height, checking the lashing, counting the products, etc., can become factors that generate incidents. Simple controls such as an operational checklist can become an ally in accident prevention.

There is a constant need for efficient operational controls, as small deviations can result in large impacts for the safety of the entire operation.

We could spend the day just talking about the human factor, but I believe we've already lingered longer than we should in this article... so we continue on to the next article... Flyrocks – part 3 (prevention is the best medicine)...

That's it, this topic is getting bigger and bigger, I hope it's not tiring, but the idea is to spread knowledge, and those who don't need it, can just give a quick review of the topics, while we hope that others can pay attention to some details , that need to be improved in their operation, and so, who knows, we can prevent incidents from happening...

In our next article, we will finish the Flyrock topic by talking about the main preventive requests and the main points that we need to be aware of when carrying out a rock blast.

Please comment and share, and if anyone wants to make a contribution regarding this topic or any other, please do not hesitate to contact us, as our goal is to have blasts that are increasingly safe and of quality!!

Suggest topics that they believe need to be better addressed, remembering that our objective is to disseminate knowledge.

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