DESIGN AND APPLICATION OF AIR DECKS IN SURFACE BLASTING OPERATIONS

Airdecking was originally applied in the late 19th century as a means to distribute the explosives pressure more evenly throughout the rock mass being blasted. This was critical to reduce shattering in dimensional stone, yet was also recognized as a means to "stretch the powder" in conventional shooting. The technique was restricted primarily to small diameter holes using black blasting powder in dimensional stone work. Today, black powder shooting in dimensional stone quarries is the exception rather than the rule.

MODERN APPLICATIONS

Today air decking is being used succesfully around the world to allow reductions of from 10% to 30% in total explosives required for production blasting. With the increased pressure on operators in large volume operations to reduce blasting costs, potential savings of this magnitude cannot be ignored.

Other common applications of airdecking are for wall control, rip-rap production, to reduce vibration/overpressure and to create a barrier to groundwater using pre-splitting techniques.

In all these cases, air decking can result in substantial savings and improved efficiencies over conventional methods.

PRODUCTION HOLES

In designing the burden for production blast-holes, the engineer is restricted to how much ground the hole can pull at the toe. This is the most heavily constricted area of the hole and proper fragmentation and movement in this zone is critical. At the top (or "collar") of the hole, there is much less vertical constriction, so it follows that considerably less explosive energy is required to fragment and move the material at the top of the hole than at the bottom.

Common practice to compensate for this is to use a lower energy/density explosive in the upper region of the hole. Generally speaking, there is no lower density, lower cost explosive for the upper region than AN/FO, and this in fact is the one most commonly used.

When blast engineers design the pattern to pull the toe with AN/FO as the ***total*** charge, things get a bit more complex. Operators can use bulked out AN/FO mixtures to achieve similar energy reduction in the collar zone, but the added time and effort often make this impractical.

Air decking offers an economical and energy efficient alternative to this practice.

The physical steps in creating an airdeck are simple :

1. Lower the design top of the explosive column
2. Set a barricade to the stemming material at some point above the original top of column location
3. Stem from this barricade to the top of the hole, as usual

The explosive gases will be able to expand into the air deck created above the column and exert a reduced but ***prolonged*** stress in the collar zone of the hole. This can allow significant reductions in the total explosives loads in production holes without significant loss in either fragmentation or movement of the collar zone.

DESIGN CRITERIA

The most common design criteria used to estimate an air deck volume is a percentage of the total explosive column length. When working in a fairly tight range of diameters and hole lengths, this approach works quite well. This method has the added advantage of automatically giving the operator an accurate estimate of how much will be saved in explosives costs.

The new stemming length is usually started at 75% of the original - but this is dependant on the degree of risk for stemming ejection or fly-rock. Gradual reductions in stemming length will determine the minimum allowable, and this can often be as little as half of the original stemming length provided good stemming material is used.

Carefully controlled field tests are required for exceptional conditions (rock or explosives types, holes diameters or depths). It is recommended that these tests begin with the minimum amount of stemming and explosives removed, with gradual increases in each until the maximums that can be removed are determined.

PRESHEARING

Preshearing (or ”Pre-splitting”) is generally an expensive process, both from a drilling and from a blasting perspective. Drill factors can be as low as 15% of normal production which in turn means that the drilling cost per ton is increased over six-fold. In addition, there is a low yield of rock per man-hour loading when compared to normal production holes. In the loading process, high cost, specialty explosives are often used, or labour intensive preparations of string charges are involved.

Air decking with bulk explosives offers two methods of reducing the impact of lower drill factors and high explosives costs.

1. Air deck pre-shearing is conducive to large diameter holes - normal production diameters can be used, usually at much wider spacings than small diameter holes. This, in effect, reduces the impact of lower drill factors on drilling and loading costs.
2. Bulk explosives are considerably less expensive to purchase and load than specialty or hand-prepared string charges.

DEWATERING LARGE BLOCKS OF GROUND

This technique involves the pre-shearing of target blocks well in advance of production drilling. Pre-shear charges are generally slightly heavier than normal to ensure wide, full-depth cracks. Ground water drains into these cracks and is able to escape at floor level into the previous excavation, resulting in a dry, isolated block of material.

For operations already committed to pre-shearing for wall control, the only added cost is a slight increase in required explosives. For those operations not using wall control, this technique offers an added argument for wall control implementation.

When combined, the benefits of wall control and dewatering can help maintain more uniform fragmentation, controlled blast displacement, more stable high walls and reduce wet hole explosives costs.

DESIGN CRITERIA

Since more in-depth design criteria is presented in the attached material, a very basic method of arriving at approximate values is presented here, based on the production pattern.

1. Spacing equals from 1/2 to 1/3 of normal spacing
2. Burden equals from 1/3 to 1/4 of the normal burden
3. Charge equals from 0.5 to 1.0 kg per square meter of final wall

VIBRATION AND OVER-PRESSURE REDUCTION

When vibration problems are the result of charge per delay, the simple expedient of introducing air decks in the production holes can help. The resultant reductions in vibration levels are primarily due to the simple reduction of charge in each hole. There is some evidence to support the claim that the air deck also acts as an "accumulator", trapping previously wasted energy in the collar zone and converting it into useful work. This may further reduce vibration levels in the near field.

Over-pressure due to stemming ejection can also be reduced through the use of air decks. In addition to effectively lowering the top of the explosive column, air decks can act as stemming enhancers. Coal operators have been able to solve stemming ejection problems by simply inflating an air bag directly on top of the explosive column before stemming the hole.

A second major cause of overpressure is the transmission of the explosive shock wave from the rock surface into the atmosphere. Efficient pattern design and implementation, coupled with proper delay sequencing, can go a long way to reducing the magnitude of the shock wave introduced into the atmosphere, but can't eliminate it. Air decking, by the simple expedient of reducing the total explosive amount, can reduce it even further.

Two surfaces must be considered - the vertical surface at the front of the shot (normally called the free face) and the horizontal surface on the top. Shock waves from the vertical face are least affected by air-decking, since the air deck itself comprises a relatively small portion of the vertical section of the blast. The shock wave off the horizontal face is most affected by air decking, where the deck (1) reduces the total explosive amount, and (2) increases the distance the shock wave must travel through the rock before it reaches the surface.

A third mechanism in over-pressure reduction could be the "accumulator" effect noted previously.

TEST RESULTS

Over a two year period, demonstrations and tests with air decks were carried out in a wide variety of mines, and one quarry, in Peru and Venezuela. These included two iron mines, one limestone quarry, one coal mine, two gold mines, one poly-metallic mine and two copper mines. The objectives of these tests were to :

1) improve fragmentation in the top zones of the blasts,
2) demonstrate how to implement air decks as standard practice in production blasts,
3) develope an air deck loading procedure that was at least as efficient as, and preferably faster and simpler than, the normal loading procedure
3) demonstrate sufficient explosives savings to offset the cost of the air decking device
4) demonstrate the design and implementation of air decks for wall control

In all tests involving top air decks, surface fragmentation with properly designed and implemented air decks was equal to or better than that achieved with normal practice.

In the one test with a mid-column airdeck, fragmentation was judged equal to normal, but this was a subjective assesment on the part of the shovel operator.

Only minor adaptations were required to the bulk explosives trucks on the tests, consisting of attaching the inflation hose kit to the air tank on the truck brake system. Training was rapid and intuitive, rarely requiring more than fifteen minutes, and the additional step of lowering and inflating the air decking device was acceptable to the loading crews.

During the demonstrations, the time to place the air decking device was between five and twenty five seconds per hole - this included lowering the device into the hole, inflating it and retrieving the inflation hose. The main variables in total time were the size of the bore hole (which defined the size of inflatable device to use) and the length and diameter of the inflation hose. For example, the longest time in any of the tests (25 seconds) was reduced to 10 seconds by simply removing six meters of un-necessary hose and several connectors.

Stemming time was reduced by from 25% to 50%, considerably more than the extra time taken to place the air decking device. In addition, there was a substantial reduction in the amount of stemming material required. This was a major issue in one mine that used crushed stone as stemming material.

The initial air deck designs in all the mines visited were based on removing just enough explosives to offset the purchase price of the air decking device. In all cases, the operators insisted on removing at least double, and in two cases three times, this amount. There was no discernable differance in the blast results between the minimums and maximums of these values.

Air decking for wall control was demonstrated at only one mine, and no clear conclusion could be drawn on the results of this demonstration. The wall that was blasted was not scheduled to be dug out for two weeks, by which time the tests would have been concluded and the participants returned to the United States. The drill/blast foreman at the mine affirmed that the results from all test configurations were "acceptable" during a follow-up call one month later, but it was not possible to enter the mine at that time to confirm this.

CONCLUSIONS

The most important thing for an operator to keep in mind is that these techniques do work and are being used as standard operating procedure in a wide variety of applications. As in any technique, there will naturally be situations where air decking will not be feasible - either due to economics, convenience or geology.

In summary, the potential benefits of air decking include :

1. improved fragmentation in the collar zone of the blast
2. a faster loading cycle
3. reduced crushed rock requirements for stemming material
4. reduced vibration and overpressure levels
5. improved costs and production in wall control drilling and blasting
6. a savings in overall explosives costs

From Numerical modelling of the effects of air decking/decoupling in production and controlled blasting, L. Liu and P. D. Katsabanis, Fragblast 5, Montreal, Canada

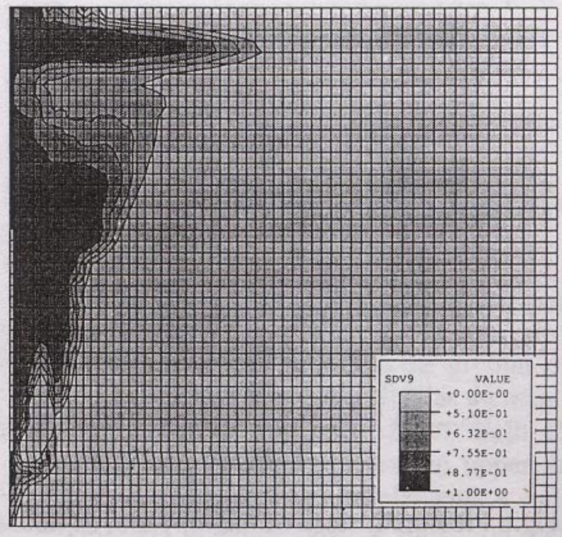

Fig. 3 Damage contours of the model with full stemming, showing two damage zones at critical state

Figure 1

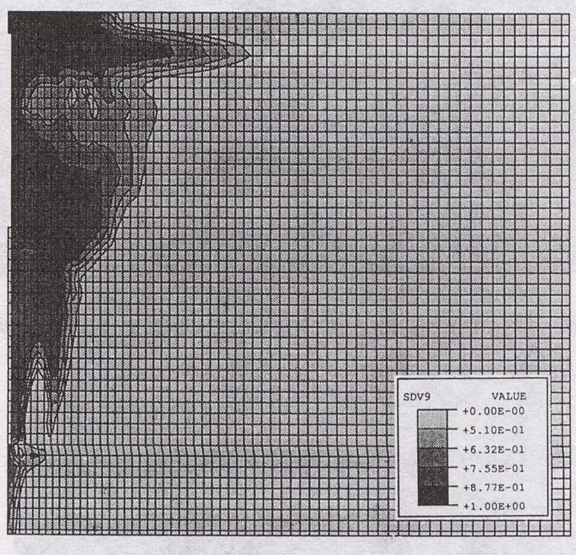

Fig. 11 Damage contours at an air deck length 1.44m

Figure 2

From Numerical modelling of the effects of air decking/decoupling in production and controlled blasting, L. Liu and P. D. Katsabanis, Fragblast 5, Montreal, Canada

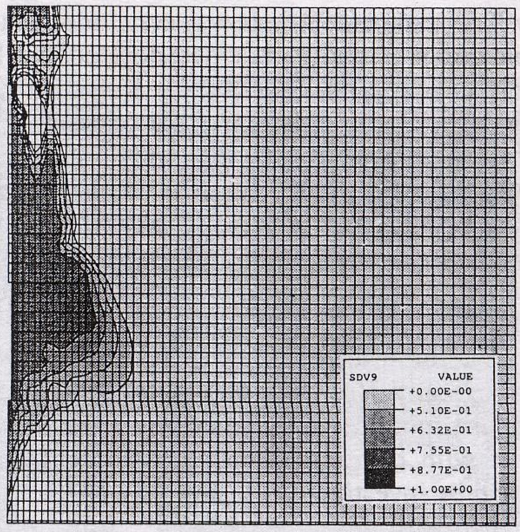

Fig. 18 Damage contours with a bottom air deck, explosive top initiated

Figure 3

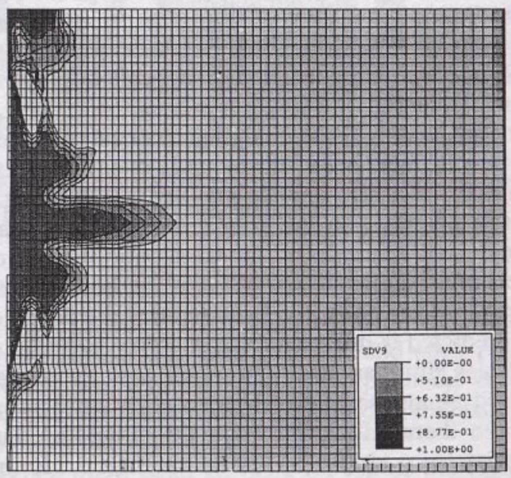

Fig. 19 Damage contours with a mid-column air deck, explosive columns initiated simultaneously from opposite ends

Figure 4

From The application of mid-column airdecks in full scale production blasts, T. Davids and B.J. J. Botha, Fifth High Tech Seminar State of the Art Blasting Technology Instrumentation and Explosives Applications, Blasting Analysis International

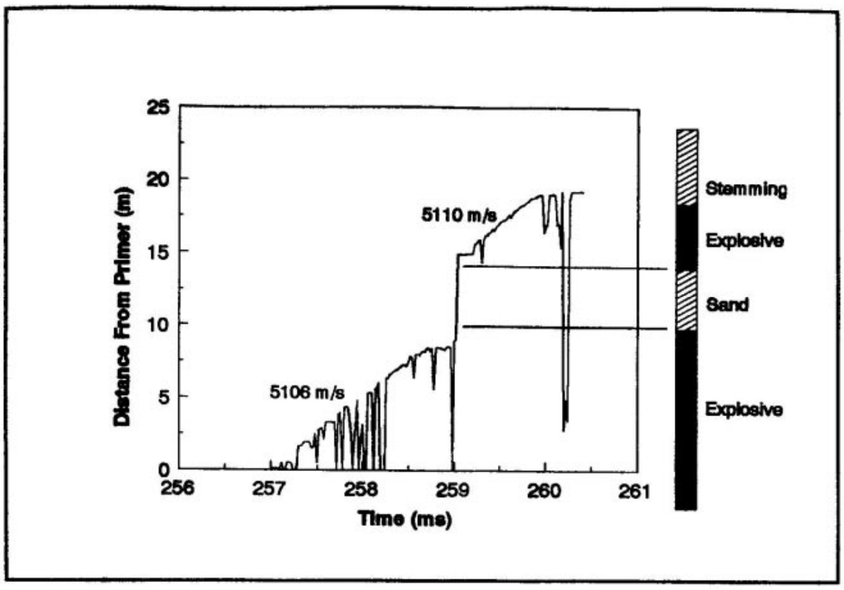

Figure 5 - VOD trace through inert deck

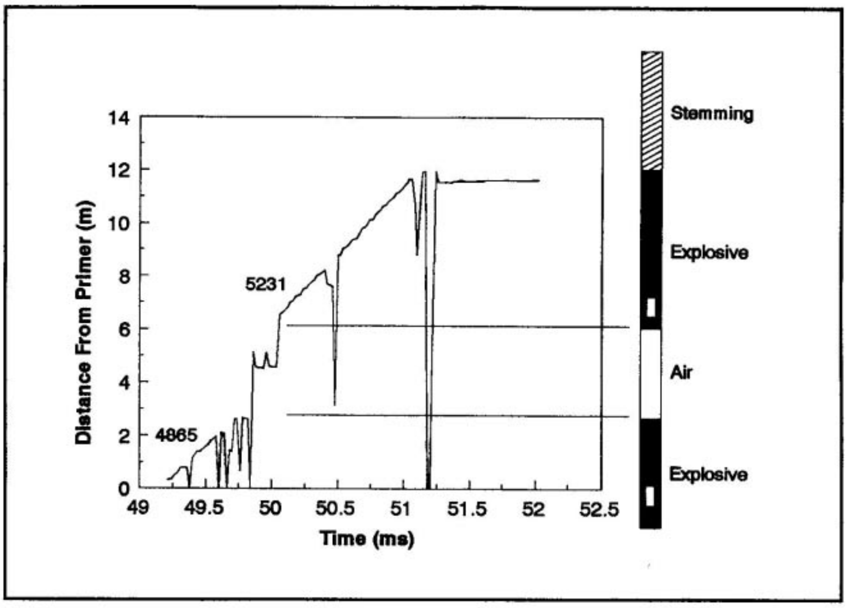

Figure 6 - VOD trace through air deck

From The application of mid-column airdecks in full scale production blasts, T. Davids and B.J. J. Botha, Fifth High Tech Seminar State of the Art Blasting Technology Instrumentation and Explosives Applications, Blasting Analysis International

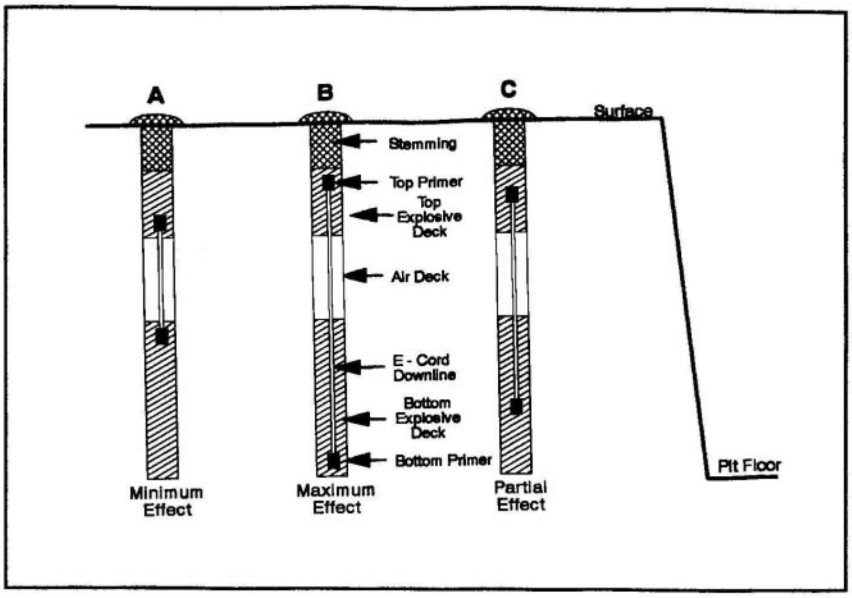

Figure 7 - effect of primer location, detonating cord length between primers

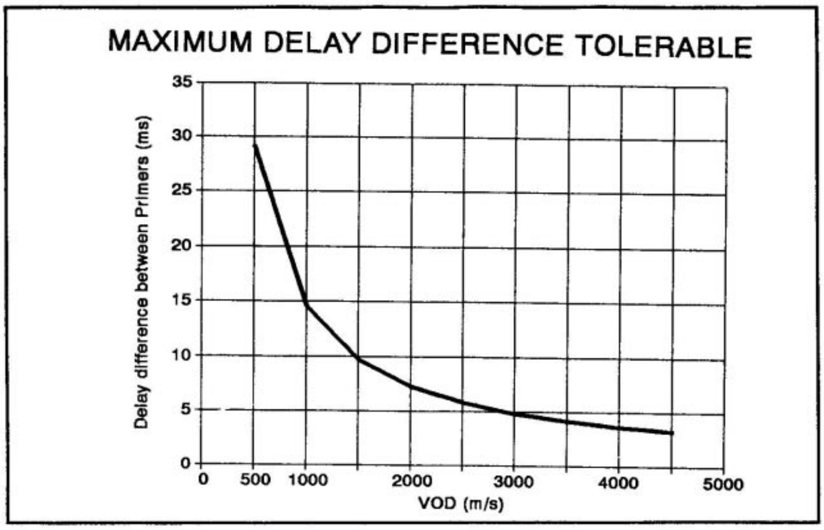

Figure 8 - effect of VOD on acceptable time variance over a 5 meter mid-column air deck

From A study of free toe-space explosives loading and its application in open pit blasts, G. J. Zhang, Fragblast 5, Montreal, Canada

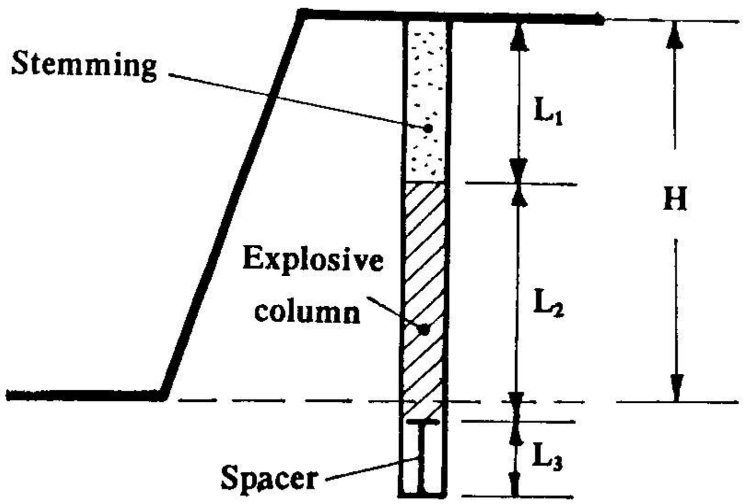

Figure 1. Bottom-space loading structure for open pit blast.

Figure 9

Table 1. Tensile and compressive strength of rocks at the test sites.

Rock type	Tensile strength (MPa)	Compressive strength (MPa)
Iron ore	7.6	154.6
Serpentinite	4.5	92.5
Dolomite	4.6	94.8
Skarnization marble	10.5	214.3
Skarn	6.5	133.7

Figure 10

From A study of free toe-space explosives loading and its application in open pit blasts, G. J. Zhang, Fragblast 5, Montreal, Canada

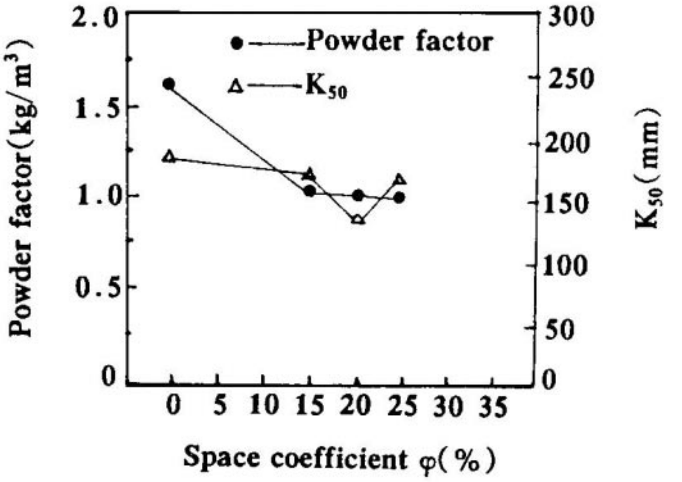

Figure 3. K_{50} and powder factor vs. space coefficient φ for blast in the Iron ore.

Figure 11

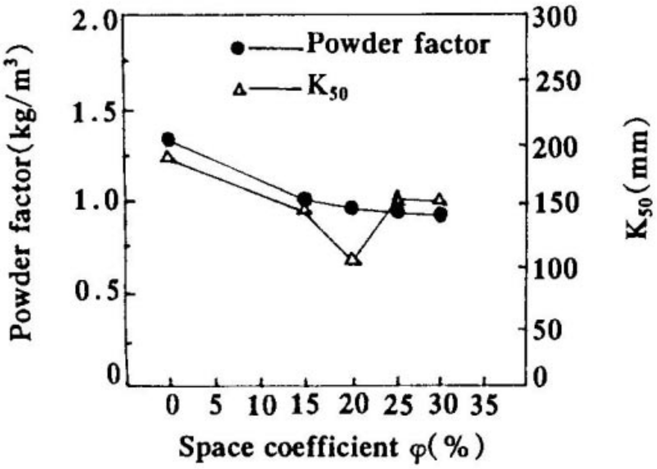

Figure 6. K_{50} and powder factor vs. space coefficient φ for blast in Skarnization marble (water bottom-space hole).

Figure 12

CUSTOMER INFORMATION AND ESTIMATE SHEET (per shot)

CUSTOMER ______________________________ DATE _________

ROCK TYPE ______________________________

Hole diameter	311	mm	METRIC
Hole depth	18	meters	
Standard stemming	7	meters	
Burden	7	meters	
Spacing	8	meters	
Subgrade	1.5	meters	
Explosive density	0.8	gm/cc	
Explosive cost	$0.33	per kilogram, in the hole	
Price of bag	$6.50		
kg/m. rise	60.77		
$/m. rise	$19.75		
Proposed air deck	3.11	10.00	x borehole diameter
Proposed stemming	5.25	0.75	x standard stemming
Potential savings	$20.36	per hole	
Holes per shot	80		
Potential savings	$1,628.88	per shot	

CUSTOMER INFORMATION AND ESTIMATE SHEET (annual)

CUSTOMER ____________________ DATE ________

ROCK TYPE ____________________

Annual production, BCM	10,000,000
OPEN TWO FACES	
Percentage of production	75
Theoretical drill factor, BCM/m.	56.00
Actual drill factor	51.33
Total holes	8117
Sub-total 1, savings	$165,268.18
OPEN ONE FACE	
Percentage of production	20
Number of lines per shot	11
Actual drill factor	46.67
Total holes	2381
Sub-total 2, savings	$48,478.67
TIGHT	
Percentage of production	5
Number of rows per shot	15
Number of lines per shot	3
Actual drill factor	31.94
Total holes	870
Sub-total 3, savings	$17,707.31
TOTAL ANNUAL SAVINGS	$231,454.15

SPREADSHEET FOR PRE-SHEAR DESIGN/COMPARISON

CLIENT ____________________________________ DATE _______________

ROCK___________________________________ METRIC SYSTEM

Hole diameter	100	mm	Recommended range	
Hole depth	10	meters	from	to
Collar	1.05	meters	0.90	1.20
Spacing	1.35	meters	1.20	1.50
Burden	1.65	meters	1.50	1.80
Sub-grade	0	meters		
Sp. Gravity of explosive	1.25	gm/cc		
Price of explosive	$2.00	/kg		
Price of drilling	$5.00	/m	Recommended range	
Price of air bag	$0.00		from	to
Charge per hole	10	kgs	7	14
Holes loaded per man-hour	4			
$/hour for labour	$50.00			
$/initiator	$4.00			
$/primer	$4.00			
Holes per blast	400			

Charge per square meter of final wall	0.74	kg
	$90.50	per hole
Unit costs	$6.70	per square meter of final wall
	$4.06	per cubic meter
Total cost	$36,200.00	

SPREADSHEET FOR PRE-SHEAR DESIGN/COMPARISON

CLIENT ____________________________________ DATE _______________

ROCK___________________________________ METRIC SYSTEM

Hole diameter	200	mm	Recommended range	
Hole depth	10	meters	from	to
Collar	2	meters	1.80	2.40
Spacing	2.7	meters	2.40	3.00
Burden	3.3	meters	3.00	3.60
Sub-grade	0	meters		
Sp. Gravity of explosive	0.8	gm/cc		
Price of explosive	$0.35	/kg		
Price of drilling	$10.00	/m	Recommended range	
Price of air bag	$4.50		from	to
Charge per hole	25	kgs	14	27
Holes loaded per man-hour	12			
$/hour for labour	$50.00			
$/initiator	$4.00			
$/primer	$4.00			
Holes per blast	200			

Charge per square meter of final wall	0.93	kg
	$120.92	per hole
Unit costs	$4.48	per square meter of final wall
	$1.36	per cubic meter
Total cost	$24,183.33	

Acknowledgements

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