CHAPTER 30

Planning the work of drilling and blasting

30.1 INTRODUCTION

When undertaking a rock excavation project, one of the most important stages is the planning of drilling and blasting, not only because these two basic operations of the work cycle must be coordinated but because it is fundamentally necessary to put together a series of aspects and known characteristics of the whole operation such as the geological and topographical environment, loading and haulage equipment, posterior use of the materials, etc.

This fact, along with the influence which the actual drilling equipment can have on the rest of the operations: loading, haulage and crushing, as well as on the predicted work schedules, time allowed and operational costs, make the planning of rock excavation receive special treatment by the engineers in charge.

30.2 FACTORS THAT HAVE INFLUENCE ON THE PLANNING OF DRILLING AND BLASTING

The factors which must be known to properly plan the work can be classified as: general, when they affect the whole project or intervene in long term plans, and operative, when they affect specific aspects or short to medium term plans.

The most important general factors in surface projects are:

- The amount of rock to be excavated. Work schedule and time limit.
- Loading equipment to be used.
- Bench height.
- Geometry of the excavation.
- Geographical situation.
- Geomechanic and structural properties of the rocks.
- Required fragment size distribution.
- Environmental limitations.
- Global cost of drilling and blasting.

Some of the operative factors are:

- Number of benches in the operation.
- Length of operational faces.
- Accesses to different levels.
- Advance sequence.
- Number of blasts, etc.

30.2.1 *Amount of rock to be excavated. Work schedule*

The volume of rock which must be moved, the set time limit and the general organization of work all intervene to determine the excavation schedule in units of time: year, month, week, day and hour.

Lost time or setbacks that are characteristic of any operation must be taken into account, such as night work, the moving of drilling equipment, changes in the line of progress, interruptions during blasting, bad weather, traffic, etc., or factors such as experience of the operator, coordination with other production equipment, etc.

Each rig should be considered part of a system and, as such, is subject to lost time owing to faulty direction, supervision, work conditions, climate, etc. These setbacks and lost time characterize what is known as operative efficiency.

On the other hand, the mechanical availability or just availability must be taken into account, which can be defined as a measure of machine performance during the programmed time. Lost work hours due to sudden breakdowns and to programmed repairs or maintenance must be accounted for.

When there is not enough information to estimate the previously mentioned factors individually, the product of both can be taken, called *global operative effeciency*, which is given in Table 30.1.

If the climate is extreme and the environment dusty, with compact and abrasive materials, the quality of the operation can be considered poor and the output will be adversely affected owing to the bad work conditions.

If the direction and supervision are excellent, with good repair shops, and the preventative maintenance programs are adequate, with minimum time lost in loading, high availability, etc., the effective production time will be high. However, a poor direction and supervision will reduce the real production time and the capacity of the equipment must be increased to achieve the necessary production rates.

Example

A hydraulic rig with top hammer is working on a 20 m limestone bench, drilling blastholes of 102 mm (4"). The penetration rate is 110 cm/min, which can be described as a drilling rate of 35 m/h. The yield of rock per drilled meter of hole for the set blasting plan is 13 m^3/m.

Supposing that the operative efficiency factor is 80% and the mechanical availability of the equipment is 90%,

Table 30.1. Global operative efficiency.

Work conditions	Quality of the organization			
	Excellent	Good	Regular	Poor
Excellent	0.83	0.80	0.77	0.77
Good	0.76	0.73	0.70	0.64
Regular	0.72	0.69	0.66	0.60
Poor	0.63	0.61	0.59	0.54

the drilling capacity is to be calculated for one and two shifts of 8 hours each.

– Capacity per shift (m^3) = Drilling capacity (m/h) × No. hours per shift (h) × Yield of rock per drilled meter of hole (m^3/m) × Operative efficiency factor × Mechanical availability of the equipment

– Capacity per shift (m^3) = 35 m/h × 8 h × 13 m^3/m × 0.80 × 0.90 = 2.621 m^3

– Capacity of two shifts (m^3) = 2 × 2.621 m^3 = 5.242 m^3

30.2.2 *Loading equipment bench height*

The loading equipment should be selected in function with the work schedule and the available transportation fleet. The bench height is determined from the shovel capacity of the loading equipment C:

– Front end loader . . . . H(m) = 5 to 10 m

– Hydraulic shovel . . $H(m) = 4 + 0.45 \times C_c (m^3)$

– Rope shovel . . . . $H(m) = 10 + 0.57 \times (C_c - 6)$

For safety measures and effeciency, bench heights over 20 m are not recommended.

30.2.3 *Geometry of the excavation*

The following should be taken into account:

– Size of the cut in breadth and depth.

– Natural ground topography.

– Accesses to the excavation area.

– Infrastructure of the work zone; electric energy, maintenance installations, service facilities, etc.

– Preparatory work.

30.2.4 *Geomechanics and structural properties of the rocks*

The following should be known:

– Geological structure of the surroundings.

– Types of rocks and densities.

– Mineralogical composition, especially if quartz is present.

– Geomechanic properties, uniaxial compressive strength, sonic velocity, etc.

– Structural data, fissures, diaclases, joints, types of filling, cavities, predominating direction of the discontinuities, etc.

– Water presence.

– Weathered material or earth overburden.

30.2.5 *Required fragment size distribution*

The necessary size distribution is in function with the posterior treatment and use it is to recieve, and in some instances, the capacity of the loading equipment has indirect influence.

If the block size T_b is expressed by its largest size, then the following types of projects can be given:

– Material that can go through the crusher. This is the case of surface mine ore and dry materials in quarries. The following should comply:

$$T_b < 0.8 \times AD$$

where: AD = Admissible size in the crusher.

– Waste material to be dumped. Depends on the shovel capacity.

$$T_b < 0.7 \times \sqrt[3]{C_c}$$

where: C_c = Shovel capacity (m^3).

The optimum block size is usually that which has a relationship to the shovel capacity of between ⅙ and ⅛.

– Material for rockfill. Usually the maximum size is not over 70% of the thickness of the layer.

– Material for harbors and dams. The written conditions usually contemplate different areas that correspond to nucleuses and coverings of core and shell material, protective coverings and barriers, etc., each have a different average size distribution that goes from 0.5 t to more than 12 t per block.

30.2.6 *Environmental limitations*

The disturbances that blasting produces and should be kept within the safety limits are:

– Ground vibrations. There should be on hand a table of charge/distance drawn up from the maximum level allowed.

– Airblast. The explosive should be confined as well as possible, along with use of the proper initiation sequence.

– Flyrock. A safety distance should be defined for installations and machinery, and if the design of the blasts warrant it, protections should be used.

– Dust. This is impossible to completely eliminate and can only be controlled by surface watering, which does not give very practical results.

The type of blast can be conditioned in a significant manner by environmental limitations and by other factors of operative nature such as: damage to remaining rock, fragmentation, heave or muckpile profile, excessive fines, separation of ore/waste, etc.

In surface mining, the following blasting techniques can be taken into consideration.

a) Bulk mining using bench blasting e.g. large scale waste removal in coal and metalliferous mines.

b) Selective mining using bench blasting e.g. ore/waste separation at mining face, common in iron ore and gold mining operations.

c) Controlled blasting techniques at the pit limits e.g. presplitting.

d) Bulk paddock blasting e.g. used to break up caprock ›ove some bauxite orebodies.

e) Selective mining using paddock blasting e.g. gold e blocks and waste blocks are then dug separately.

f) Secondary blasting using drillholes e.g. popping.

g) Secondary blasting without using drillholes e.g. ud capping.

h) Bulling a blasthole to increase its capacity to hold further explosive in order to break a large tonnage of rock per hole.

i) Quarrying dimension stone e.g. blasting powder to achieve minimum shattering.

j) Coyote blasting uses small tunnels and chambers to locate large quantities of explosives which are instantaneously shot eg up to one million tons have been produced in a single shot in this manner.

›le 30.2. Surface mine blasting techniques and associated limitations (Little and Van Rodijen, 1988).

ısting tech limitation	Limits blast	Paddock bulk	Paddock sel	Secondary pop	Secondary blast	Bench bulk	Bench sel	Coyote blast	Bulling	Dimension stone	Drop cut	CTB
ck damage	A	U	A	U	U	A	S	S	S	A	U	S
ıgmentation	S	A	A	A	A	S	A	A	A	S	S	S
ave	U	A	A	U	U	A	A	S	S	S	S	A
ɛ/waste se[	U	U	A	U	U	U	A	U	U	U	S	S
ıes	U	U	U	U	U	U	S	U	U	U	U	U
'rock	S	S	S	A	S	S	S	S	S	U	S	S
·blast	U	S	S	S	A	S	S	S	S	S	S	S
›ration	A	S	S	U	U	S	S	A	A	S	S	S

gend: A = Always influences the blast design, S = Sometimes influences the blast design, U = Unusual for this aspect to influence the blast design.

ble 30.3.

		DRILLING EQUIPMENT							EXPLOSIVES AND ACCESSORIES		BLAST DESIGN		
GENERAL FACTORS	A. BLASTHOLE DIAMETER	B1. DRILLING METHOD	B2. PROPULSION SYSTEM	B3. BOOM AND FEED	B4. DRILL STEEL	B5. DRIVE	B6. COMPRESSOR	B7. DRILL BITS	C1. TYPES OF EXPLOSIVES	C2. TYPES OF ACCESSORIES	D1. GEOMETRIC BLAST PATTERN	D2. INITIATION SEQUENCE AND DELAY TIMING	D3. SIZE OF THE BLASTS
		A*		B1	A, B1, B3		A, B1, B4	A, B1, B4	A	A, C1	A, C1	C2	
VOLUME OF EXCAVATION PRODUCTION WORK CYCLES	O								O	O			O
BENCH HEIGHT	O			O	O		O			O	O		O
GEOMETRY OF THE EXCAVATION	O		O	O							O	O	O
GEOGRAPHICAL LOCATION	O		O			O							
GEOMECHANIC AND STRUCTURAL ROCK PROPERTIES	O	O			O		O	O	O		O	O	
REQUIRED SIZE DISTRIBUTION	O								O	O	O	O	O
ENVIRONMENTAL LIMITATIONS	O					O				O	O	O	O
GLOBAL COST OF DRILLING AND BLASTING	O	O				O			O		O		O

Implicated criteria

k) Drop cut blasting is used to open up a new bench e.g. to create a new vertical free face for subsequent bench blasting.

l) Controlled Trajectory Blasting (CTB) or throw blasting is used to fragment and move large amounts of overburden directly in order to reduce dragline rehandle.

Table 30.2 indicates the degree to which blasting constraints discussed above influence the design of the various surface mining blasting techniques.

30.2.7 *Global costs of drilling and blasting*

Drilling and blasting are indispensable in rock fragmentation when mechanical breakage equipment cannot be used. These operations are integrated in a system along with the rest of those that constitute an operational cycle.

The sum of the unitary costs of all operations in the cycle show different scenes, Fig. 30.1. Under normal conditions, the excavation is said to be balanced, Zone B, if the lowest total production costs are reached. When this is not possible then work is being done in Zone A, with excessive amounts of explosive, or in Zone C, with insufficient explosive, which will elevate the total costs and, in the last case, secondary fragmentation must also be included.

On the other hand, if one takes into consideration the magnitude of the environmental impacts associated with each of the previous situations, it can be observed in Fig. 30.2, that in Zone A quite high levels are reached owing to the important quantities of explosives used in proportion to the amount of rock broken, which produces intense vibration and noise. In Zone C, as a consequence of pop shooting operations, the magnitude of the impact increases considerably owing to noise, airblast and possible flyrock.

Therefore, the convenience of working in the B zone has been demonstrated, not only for economical reasons but also for environmental ones. There are less disturbances as the explosive energy that develops is put to best advantage.

30.3 PLANNING THE STAGES OF EXCAVATION

The analysis of the aforementioned factors permits, according to the pattern shown in Fig. 30.3, definition of the

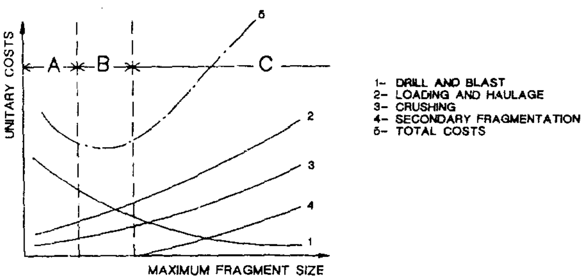

Fig. 30.1. Variation of the unitary costs with maximum size fragments for excavation situations A – Overbalanced, B – Balanced and C – Underbalanced (Dinis da Gama, 1990).

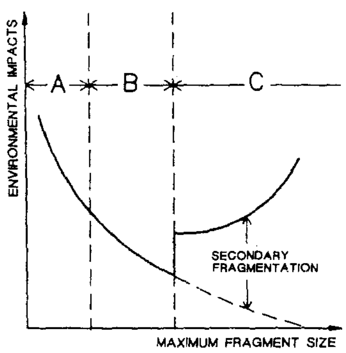

Fig. 30.2. Correlation between environmental impacts and blasting types A Overbalanced, B – Balanced and C – Underbalanced (Dinis da Gama, 1990).

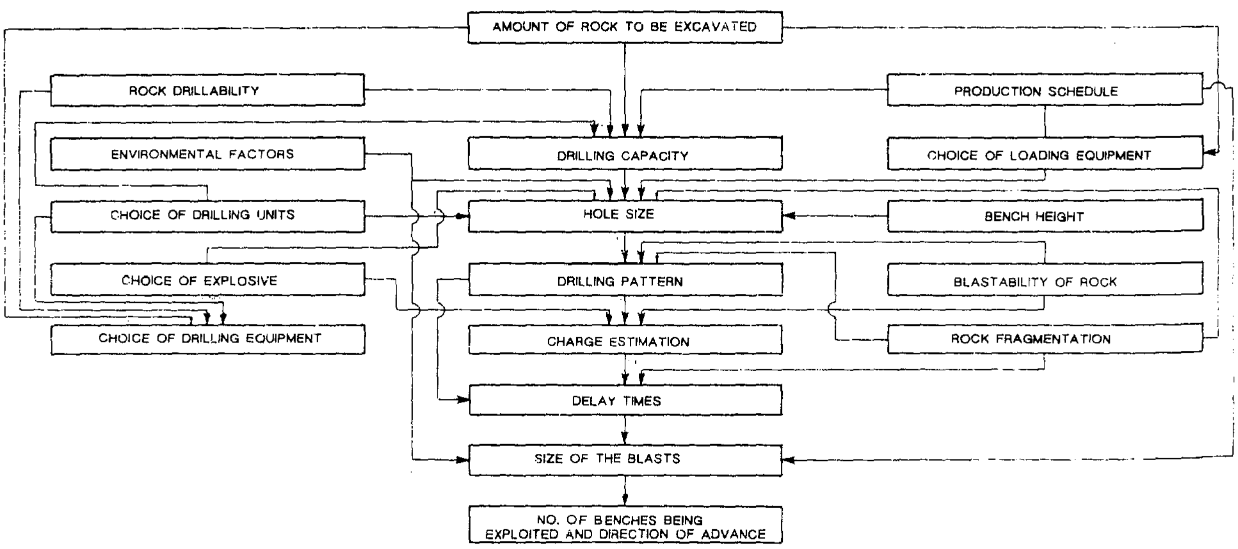

Fig. 30.3. Basic planning pattern for drilling and blasting

rinciple design criteria and the carrying out of drilling nd blasting.

- Drilling diameter.
- Rock drill characteristics.
- Explosives and accessories.
- Drilling pattern.
- Initiation sequence and delay timing.
- Size of the blasts.
- Advance direction, etc.

In Table 30.3, the interrelations that exist between the lifferent design criteria and the general factors that inter-ene in planning are shown.

The following comments might be of use:

– The drilling diameter is the most important decision o take, as it depends on a large number of considerations ind its posterior influence on the total of the operation is mmense.

– Once the diameter has been chosen, the type of rock lrill must be decided, the drill steel, the adequate feed and oom for the operation, and finally the choice of chasis or nounting system. In Fig. 30.4, the interrelation of the arameters that enter into the selection of drilling equip-nent for tunnels and drifts, and underground production lasting is established.

– The drive can be diesel and electric, depending upon echnical, economic and environmental factors.

– The selection of the explosives and how they are purchased, either bulk or cartridged, depends upon all the factors discussed in the chapter on explosive selection.

– The blasting accessories, in a similar manner, are linked with the type of explosives to be used, the planned initiation sequences and delay timings, and it can also be stated that the higher the environmental restrictions, the more sophisticated and expensive will be the explosives.

– The pattern of the blasting, burden and spacing, are in function with the blasthole diameter, the type of explosive, rock characteristics, bench height and required fragmentation. The excavation area should be divided in order to estimate, with the parameters mentioned before, the most adequate patterns for each zone – those which will give the best results at the lowest cost.

– The amount of explosive per hole could be conditioned by the maximum vibrations allowed.

– The delay timings will be chosen with the idea of eliminating the risk of flyrock and obtaining adequate fragmentation, and at the same time reducing the total operating charge of the blast.

– The initiation sequence will be established in function with the angles that are free of breakage, flyrock direction and results of the fragmentation.

– The size of the blasts should be as large as possible so as to reap the following benefits:

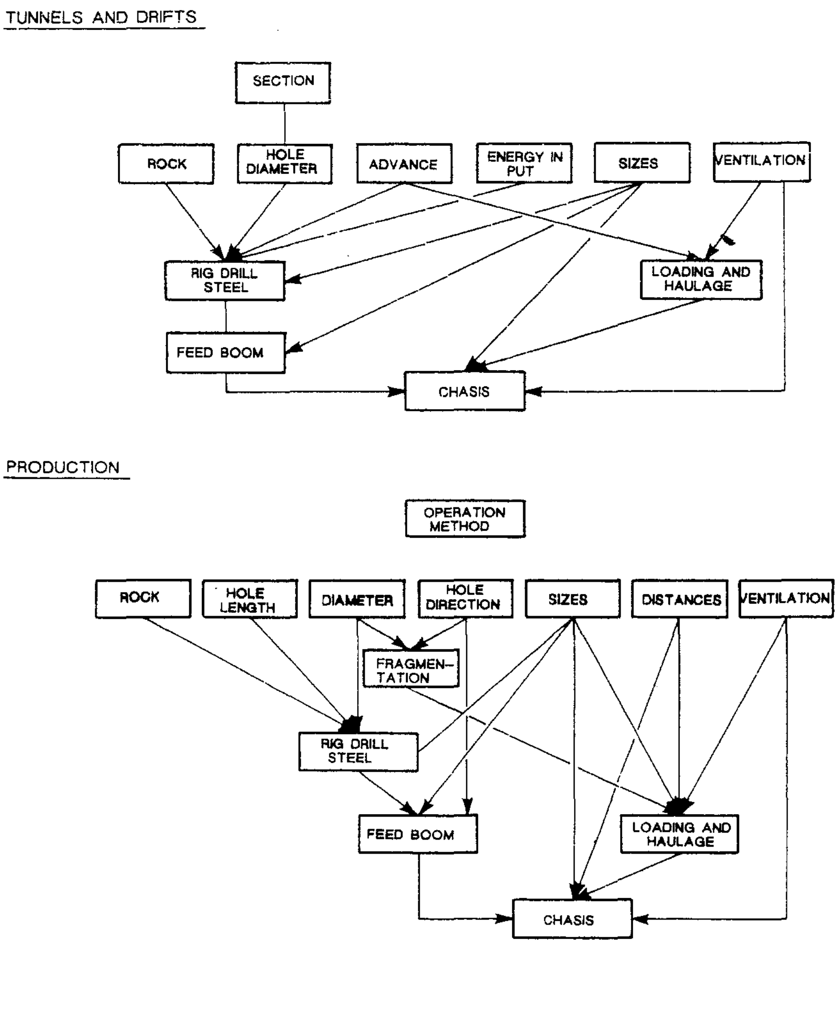

Fig. 30.4. Parameters that condition the selection of drilling equipment for underground work (Menéndez, F., 1986).