EXPLOSIVES

BLAST INDUCED GROUND VIBRATION

AIR BLAST

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INTRODUCTION

- Most rocks and ores require blasting to break them into smaller pieces before an excavation takes place in mining operations.
- Explosive materials are tools that benefit mankind, when used properly.
- However, improper use can be disastrous.
- Blasting is one of the most important parts in any mine.
- Without the appropriate performance, the results are not only the failure of the blasting operation but the mine operation could be jeopardized.

EXPLOSIVES:

- An explosive, or blasting agent, is a compound or a mixture of compounds, which, when initiated, is capable of undergoing a rapid decomposition, releasing tremendous amounts of heat and gas.
- The decomposition is a self-propagating, exothermic reaction called an explosion.
- The stable end products are gases that are compressed, under elevated temperature, to very high pressures.
- It is the sudden rise in temperature and pressure from ambient conditions that results in a shock wave traveling through the un-reacted explosive.
- The velocity of detonations lies in the approximate range of 5000 to 30,000 fps (1500 to 9000 m/s), well above the speed of sound in the explosive material.

FACTORS INFLUENCE BLASTING RESULTS

- Properties of explosives being used.
- The initiation systems.
- Distribution of the explosive in the blast.
- Rock structure and strata condition.
- The overall geometry.
- Other factors .

EXPLOSIVE PROPERTIES

- **Strength**
- **Sensitivity** - Input energy needed to start the reaction (cap or non-cap sensitivity)
- **Density**
- **Velocity of detonation (VOD)**
- **Detonation Pressure**
- **Critical Diameter- Minimum diameter in which detonation will occur**
- **Water Resistance**

TYPES OF EXPLOSIVES

- **Slurry Explosives**
- **Emulsion Explosives**
- **ANFO** - **A**mmonium **N**itrate and **F**uel **O**il

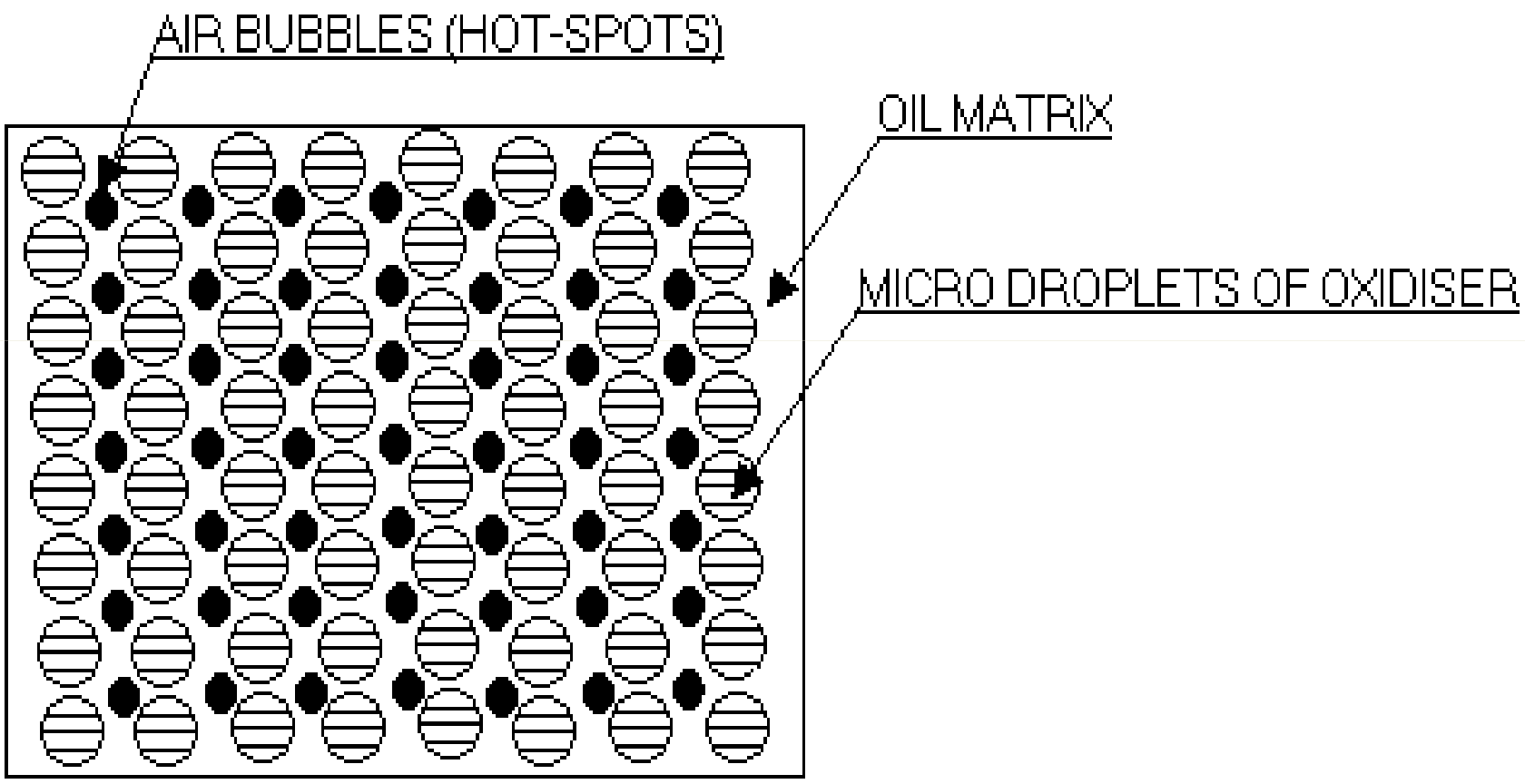
SLURRY EXPLOSIVES

- Slurry explosive is made of ammonium, calcium or sodium nitrate; a fuel sensitiser, which can either be a hydrocarbon or hydrocarbon with aluminum; along with varying amounts of water.
- Slurries or Water gels require sensitiser and a cross-linking agent..
- Slurries, in general, contain large amounts of ammonium nitrate and are made water resistant through the use of gums, waxes, cross linking agents.
- Some slurries may be classified as high explosives (made cap sensitive), while others are classified as blasting agents (non-cap sensitive) if they cannot be initiated by a number 8 blasting cap.

EMULSION EXPLOSIVES

- Emulsion explosives are the intimate and homogenous mixer of oxidiser and fuels.
- It consists of micro droplets of Super – Saturated oxidiser solution in oil matrix.
- These are in the form of water – in – oil emulsion.
- The internal phase is composed of solution of oxidiser salts e.g. Ammonium Nitrate etc. dispersed as microscopically fine droplets, which are surrounded by a continuous fuel phase.
- A bulking/gassing agent – for density control, is then dispersed thorough out the basic emulsion matrix.
- The gassing agent can either be ultra fine air bubbles or artificial bubbles from glass, resin or plastic.
- The bulking agents determine and control the sensitivity of emulsion products – whether emulsion is cap sensitive or booster sensitive.

EMULSION EXPLOSIVES



EMULSION EXPLOSIVES

PROPERTIES OF EMULSION EXPLOSIVES

1) Emulsion explosives are much better water resistant than water gel slurry or ANFO; as oil phase is at outside i.e., water phase is enveloped within oil phase (Water – in – Oil emulsion).

2) Emulsion explosives are much safer to handle, use and store as it is relatively insensitivity to detonation by friction, impact or fire.

3) High VOD can be obtained. VOD depend upon the oxidixer droplet size (0.2 to 10 micron). Therefore, toughest rock conditions can be tackled very effectively and efficiently without compromising safety standard.

4) Critical diameter of emulsion explosives again depends upon droplet size and sensitizer used. Now a days, emulsion explosives having 25mm dia cartridge are also being used for underground / tunneling blasting operations very effectively.

PROPERTIES OF EMULSION EXPLOSIVES

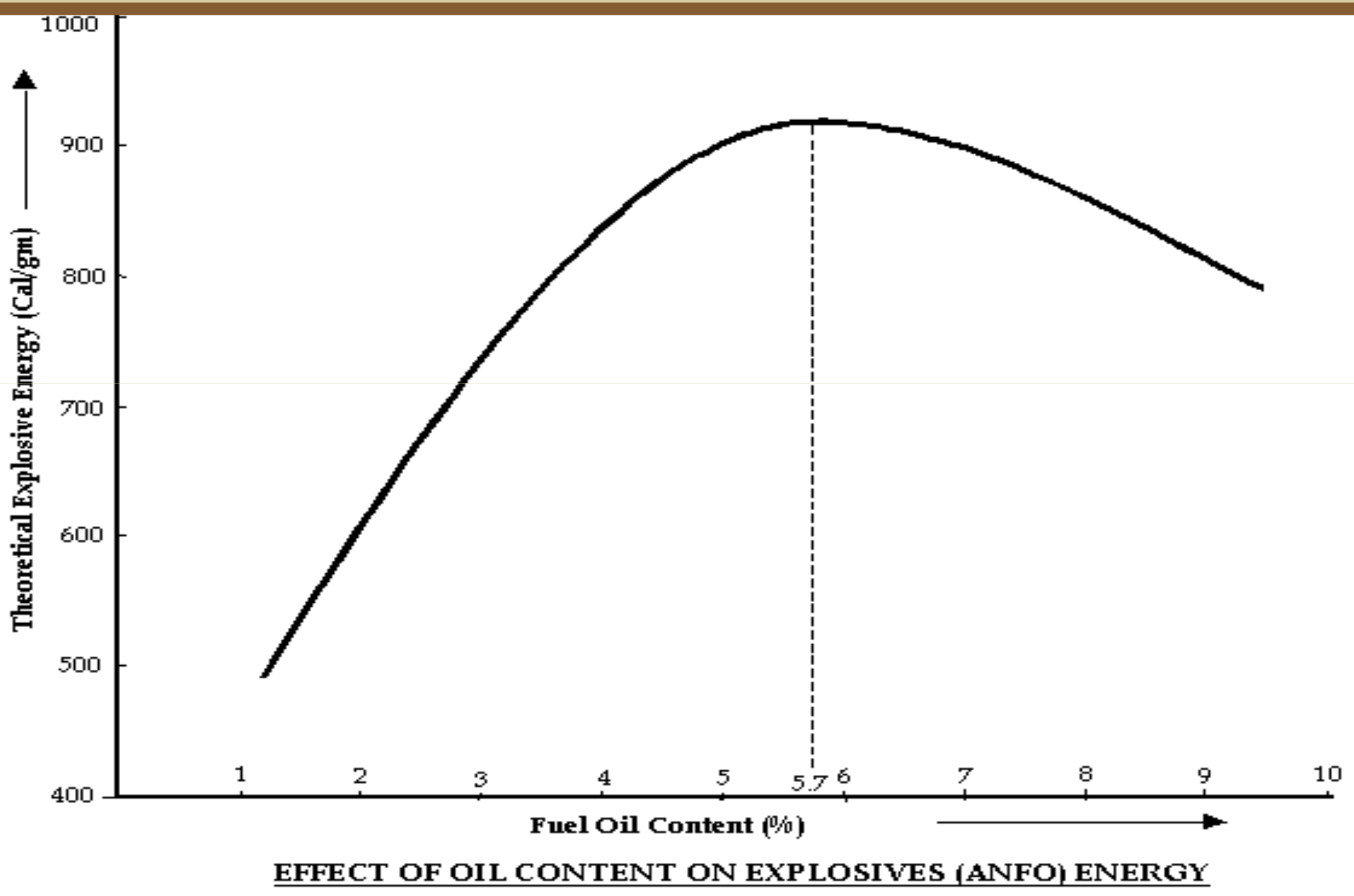
5) Because of the intimate mixture between oxidizer and fuel, emulsion explosives have higher energy than water gel slurries or ANFO and it matches with energy level of Nitroglycerine based explosives. Thus, emulsion explosives have suitably replaced hazardous Nitroglycerine based explosives all over the world without compromising performance.

6) Since Emulsion explosives are well oxygen-balanced, generates a minimum of noxious fumes and far less smoke. Post blast fume characteristics is much more favourable than NG based explosives. Hence, use of Emulsion explosives in tunneling operations have shortened the ventilation time.

ANFO : Ammonium Nitrate and Fuel Oil

- ANFO is the most common of all explosives used today, because of its economics.
- It was found that diesel oil mixed with porous ammonium nitrate prills gave the best overall blasting result
- One of the major disadvantage of ANFO is the that it is water soluble and cannot be used in wet holes
- Another disadvantage of ANFO is its low strength because of its low velocity of detonation (VOD) as compare to emulsion explosives. Low VOD is because of its solid-liquid mixture.
- The velocity of detonation is a good indicator of product performance. The higher the velocity, the greater the release of available energy.
- The oxygen-balanced ANFO mixture is 5.7 % oil and 94.3 % ammonium nitrate blasting prills. Any deviation from the oxygen-balanced mixture will result in a loss of blasting energy.

ANFO : Ammonium Nitrate and Fuel Oil



EFFECT OF OIL CONTENT ON EXPLOSIVES (ANFO) ENERGY

ANFO : Ammonium Nitrate and Fuel Oil

- **Advantages of insensitive dry blasting agents are their safety, ease of loading, and low price.**
- **In the free-flowing form, they have a great advantage over cartridge explosives because they completely fill the borehole.**
- **This direct coupling to the walls assures efficient use of explosive energy.**
- **Ammonium nitrate is water soluble so that in wet holes, some blasters pump the water from the hole, insert a plastic sleeve, and load the blasting agent into the sleeve.**
- **Special precautions should be taken to avoid a possible building up of static electrical charge, particularly when loading pneumatically.**

ANFO : Ammonium Nitrate and Fuel Oil

- **The specific gravity of ANFO varies from 0.75 to 0.95 depending on the particle density and sizes.**
- **Pneumatic loading results in high detonation velocities and higher charge concentrations, particularly in holes smaller than 3 in.**
- **When properly oxygen- balanced, the fume qualities of dry blasting agents permit their use underground.**

GROUND VIBRATION

AND

AIR BLAST

GROUND VIBRATION AND AIR BLAST

- One of the most troublesome and controversial issues facing mining and other industries related to blasting is that of ground vibration and air blast produced form blasts.
- With the general trend toward larger blasts, increased population, and spread of urban area, vibration problems and complaints have also increased.
- When an explosives charge is detonated in a blast hole, the rock immediately surrounding the charge is fractured, split apart and is displaced.
- At a certain distance from the blast holes, the explosives energy decreases to a level, which causes no further shattering or displacement and continues to travel through the rock as an elastic ground vibration.
- The ground motion is literally a wave motion spreading outwards from the blast, much as ripples spread outwards from the impact of a stone dropped into a pool of water.

CONCEPT OF GROUND VIBRATION

- The ground / rock through which the wave travels is considered to be elastic medium, composed of innumerable individual particles.
- As a disturbance, these particles are set into a random oscillatory motion, a ground motion wave being generated. Each particle transmits energy successively to the next.
- The total energy of ground motion wave generated in the rock around a blast varies directly with the quantity of explosives detonated.
- As the ground motion wave propagates outwards from a blast, the volume of the rock subject to the compression wave increases.
- Since the energy in a ground shot is distributed over successively greater volume of rock, the ground motion must decrease.
- Thus, energy losses occur with each successive transmission, so that as the ground wave spread outwards, it diminishes in intensity and the particles gradually return to the rest position.

SCALED DISTANCE

- When blast holes are under or over charged and absence of proper free face a great deal of liberated energy is wasted and converted into ground vibration, as explosion energy is not utilized in fragmenting / breaking of rock and throw.
- Broadly speaking, the key factor that controls the amount and type of blast vibration produced is EXPLOSIVES ENERGY CONFINEMENT AND THE DISTANCE OF THE STRUCTURE FROM THE BLASTING SITE.
- On this basis the concept of Scaled Distance equation has been developed:

$$\text{Scaled Distance} = \frac{\text{Distance of Structure from blast site}}{\sqrt{\text{Max. Charge wt. Per (8 ms) delay interval}}}$$

USBM PREDICTOR EQUATION

$$V = K\,(D/Q^{1/2})^{-B}$$

Where,

- **V is the peak particle velocity,**
- **D is the distance of the measuring transducer**
- **Q is the maximum charge weight per delay.**
- **K and B are site constants to be determined by regression analysis.**

$D/\sqrt{Q}$ is known as

SCALED DISTANCE

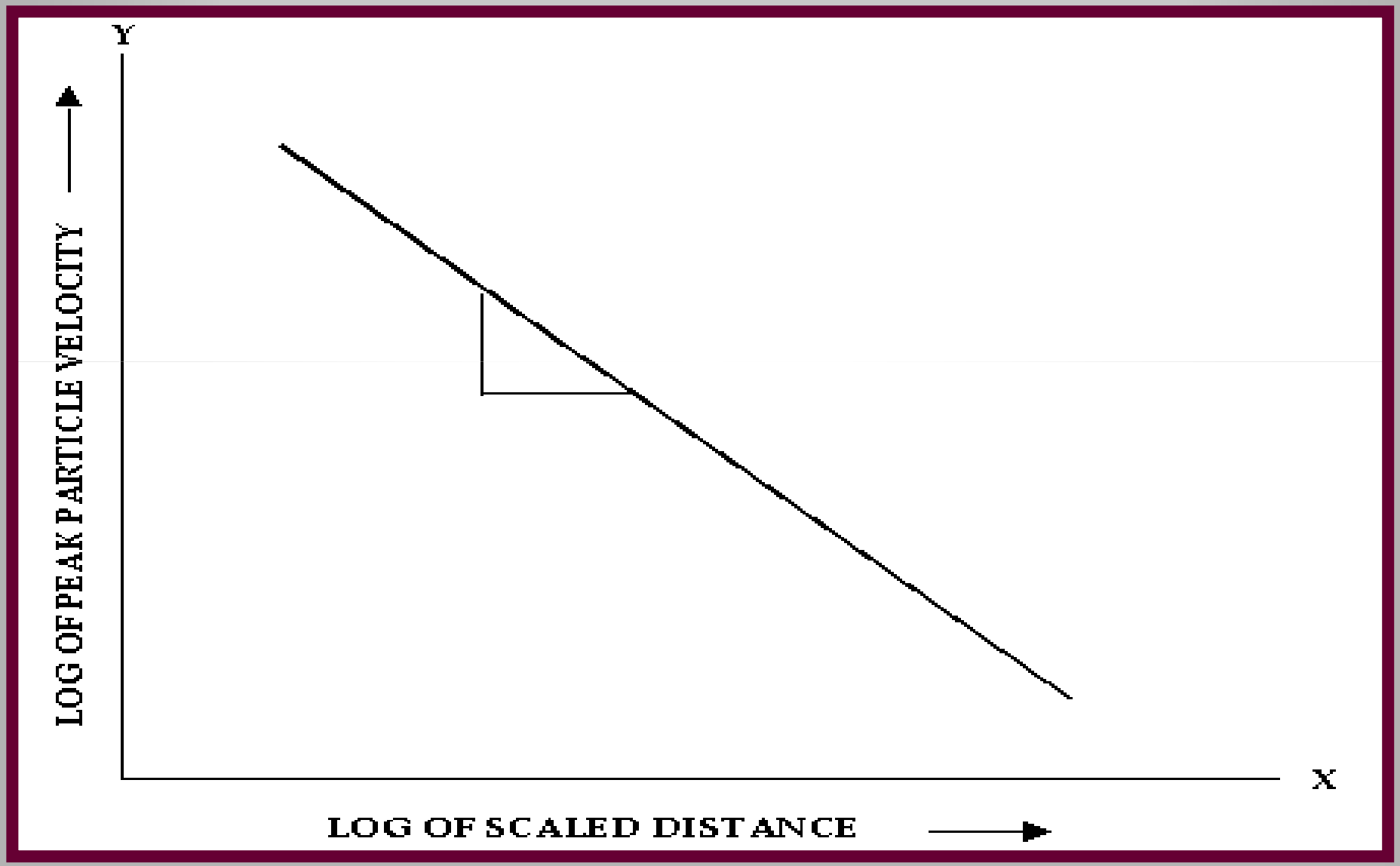
USBM PREDICTOR EQUATION

Taking Logarithm of both sides of the Predictor equation, we get:

$$\text{Log } V = \text{Log } K - B \text{ Log } (D/\sqrt{Q})$$

If, $Y = \text{Log } V$; $X = \text{Log } (D/\sqrt{Q})$ and $C = \text{Log } K$; then the above equation represents a straight line of the form $Y = C - BX$ (Straight Line plotted on Log V as Y axis and Log $(D/\sqrt{Q})$ as X axis below); where B is the negative slope of the straight line and C is the point of interception on Y axis.

Relationship of Scaled Distance with Peak Particle Velocity (PPV) on Log scale



CRITERIA FOR LIMITING SAFE VIBRATION LEVEL

Now the prime objective is to determine the maximum charge to be fired per (at least 8 ms) delay interval, in order to keep PPV within the safe limit. Following are the procedures involved:

- Measurement of PPV with different scaled distances.
- Plotting these values on a Log – Log scale as described in figure.
- The value of site constants K and B are to be determined by extrapolation of straight line plotted as described above.
- Using propagation straight line, safe scaled distance to be determined to keep PPV below safe limit (on the basis of threshold limit prescribed by DGMS, India).
- From the determined safe scaled distance above, the maximum charge per delay can be found out for various distances for a particular site.
- Besides peak particle velocity, the Frequency is one of the most important factors controlling the response of structures.

Regression Analysis

VIBRATION FREQUENCY

- Frequency is dependent on site geology, distance of the blast, delay sequence and condition of available free face of the blast.
- It has been observed that, presence of buffer in front of face holes develop low frequency waves.
- The effect of frequency generated during blasting relates to the condition of structural response and also can allow higher peak particle velocities with higher frequency.
- It has also been observed that, the ground motion frequencies are relatively high when solid or tough rock is present; frequency is relatively low when transmission medium is medium-hard / softer strata and frequency is considerably low when there is presence of void beneath.
- Thus, allowable peak particle velocity reduces considerably when there is void or underground workings beneath the structures in question.

KNOWN METHODS AND TECHNIQUES TO REDUCE GROUND VIBRATIONS :

1. **Reduce weight of Explosives per delay.**
2. **Reduce explosives confinement by :**
   a. **Reducing burden and spacing.**
   b. **Reducing buffers in front of face holes.**
   c. **Reducing stemming, but not to the degree enhancing Air Blast and/or rock Fly.**
   d. **Reducing sub-drilling.**
   e. **Reducing Hole depth.**
   f. **Using a blast design that produces maximum relief: this means using large delays between holes or rows of holes.**
   g. **Allowing at least one free face to blast.**
3. **Whenever possible, the progression of detonating holes or a row of holes through millisecond delay intervals should progress away from the structure.**

KNOWN METHODS AND TECHNIQUES TO REDUCE GROUND VIBRATIONS :

4. Use larger delays, where geological conditions in conjunction with initiation system permit.

5. Where possible, keep the total lapsed time of the entire blast below 1-second duration.

6. Use electric millisecond detonators with sequential blasting machines or an initiating system with an adequate number of delay intervals preferably, with down the hole delays causing bottom charge and deck charge blast separated by delays.

7. It has been observed that, using pre-splitting the production blast and by using air decking the ground vibration is reduced considerably.

THRESHOLD VALUE OF GROUND VIBRATION (DGMS)

TYPE OF STRUCTURE	PPV IN MM/SEC AT A FOUNDATION LEVEL OF STRUCTURE AT A FREQUENCY.		
	<8Hz	8-25 Hz	>25Hz
Building structure not belonging to owner 1.Demostic House structure kucha brick &cement	5	10	15
2. Industrial building RCC& Framed Structure	10	25	25
3.Objects of historical importance and sensitive structure	2	5	10
Building belonging to owners with limited span to life 1.Domastic houses structure Kucha bricks & cement	10	15	25
2.Industrial Building RCC & framed structure	15	25	50

AIR BLAST

- Like ground vibration, air blast is another undesirable by-product produced from blasting.
- Air blast damage and annoyance are directly related to factors such as blast design, weather and terrain conditions, and human response.
- Excessive air blast levels are an indication of poor explosive confinement.
- Unlike typical ground vibrations, air blast levels often do not decay linearly with distance.
- This is due to the focusing effects of atmospheric conditions such as wind and inversion levels.

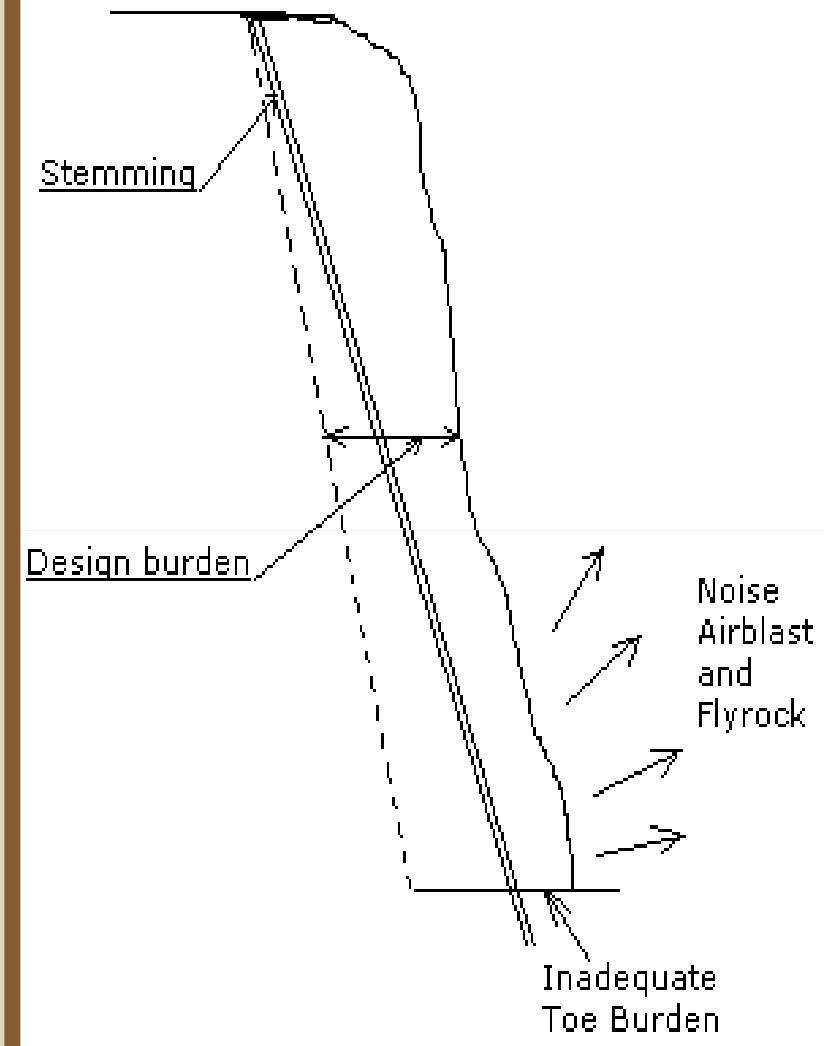
AIR BLAST

- The primary way to reduce air blast is to increase the confinement of the explosive charges and to orientate free faces away from the point of concern.

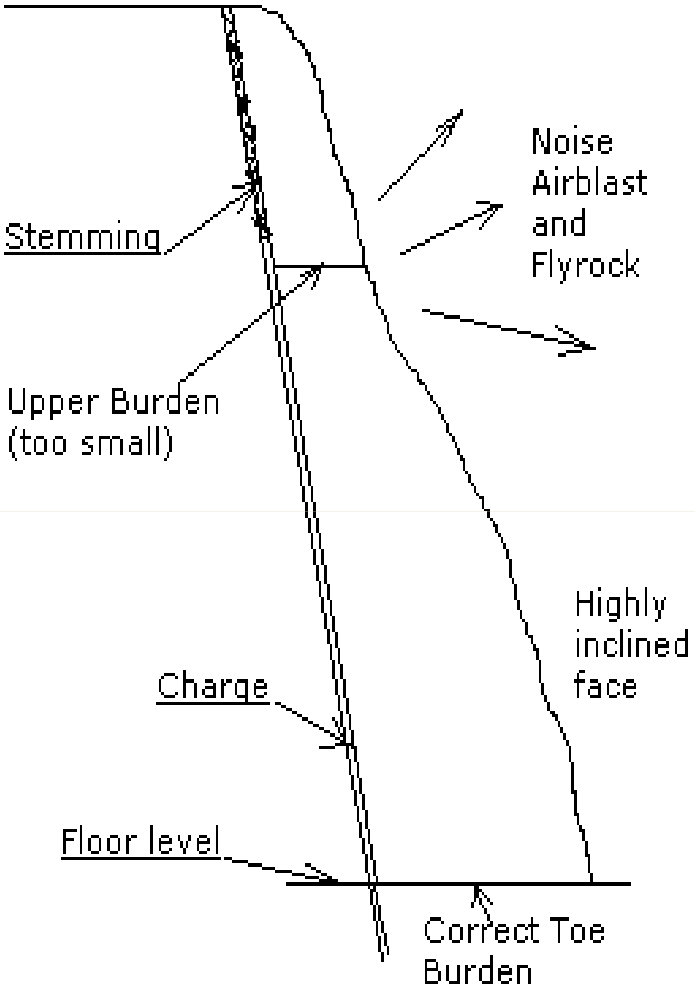
- Elements and conditions that may enhance the air blast are:

  - Detonating cord trunk lines and down- lines
  - Lack of proper stemming material.
  - Inadequate stemming height.
  - Drill patterns too small or large.
  - Secondary blasting.
  - Gas escape through fractures.

FORMATION OF FLY-ROCK



Noise, airblast and flyrock caused by an inadequate toe burden



Noise, airblast and flyrock caused by an upper burden which is too small


THANKS