ESCUELA TÉCNICA SUPERIOR DE INGENIEROS DE MINAS

PROYECTO FIN DE CARRERA

DEPARTAMENTO DE INGENERÍA QUÍMICA Y COMBUSTIBLES

UN SOFTWARE PARA EL DISEÑO DE VOLADURAS EN MINERÍA A CIELO ABIERTO

DARLINGTON MENSAH

SEPTIEMBRE DE 2012

TITULACIÓN: INGENIERO DE MINAS **PLAN: 1996**

Autorizo la presentación del proyecto

Un software para el diseño de voladuras en minería a cielo abierto

Realizado por

Darlington Mensah

Dirigido por

Pablo Segarra Catasus

Firmado: **Prof. Pablo Segarra Catasus**

Fecha: ……………………

TABLE OF CONTENT

DOCUMENT N^{O} 2: ECONOMIC STUDIES

DOCUMENT N^{O} 3: ANNEXES

LIST OF FIGURES

LIST OF TABLES

RESUMEN

Este proyecto tiene como objetivo elaborar un programa de ordenador en Visual Basic para diseñar voladuras a cielo abierto. Se realiza una revisión de las más conocidas formulas de cálculo de voladuras. Para voladuras con barrenos de pequeño diámetro (diámetro hasta 165 mm) se ha programado la formula propuesta por los investigadores sueca y para voladuras con barrenos mayores de 165 mm la formula de Konya y Walter (1990). El software incorpora, también, el cálculo del tamaño medio del escombro a partir del modelo de fragmentación Kuz-Ram, y la obtención del coste de la voladura. La eficacia del software se ha evaluado en tres voladuras realizadas en AngloGold Ashanti, Iduapriem Mine y Adamus Resources (ambos ubicados en Ghana) y Bonikro Gold Mine (Côte d'Ivoire).

ABSTRACT

This project aims to develop a computer program, using Visual Basic, to design open-pit blasting. This is achieved by reviewing the most popular blast design theories proposed by different authors. Small diameter blasting (drillholes up to 165 mm) has been programmed using the formulae proposed by the Swedish Researchers and large diameter blasting of drillholes greater than 165 mm has been programmed using the formulae proposed by Konya and Walter (1990). The software also incorporates the calculation of the average fragment size, designed using the Kuz-Ram fragmentation model, and the calculation of the cost of blasting. The effectiveness of the software has been evaluated in three pilot blasts performed in AngloGold Ashanti, Iduapriem Mine and Adamus Resources (both located in Ghana) and Bonikro Gold Mine (Côte d’Ivoire).

UN SOFTWARE PARA EL DISEÑO DE VOLADURAS EN MINERÍA A CIELO ABIERTO

DOCUMENT N^{O} 1: MEMORY

1 OBJECTIVE AND SCOPE

The objective of this project work is to develop a computational algorithm for the purpose of:

- designing a surface blast to calculate the various blast parameters.
- achieving a desirable fragmentation size at a relatively minimum cost.
- computing the total cost of blasting.

The scope of this project is limited to open pit blasting operations using one explosive type without applying the decking technique. It also considers mainly the staggered blasting technique and does not design the firing pattern of the blast.

2 BACKGROUND

2.1 PROBLEM DEFINITION

With the advancement of civilization, the requirement of different minerals has increased significantly and to meet this demand, large surface mines with million ton production targets are established. The basic aim in mining operation is to achieve maximum extraction of minerals with profit, environmental protection and safety. A rapid growth in this sector with the deployment of high capacity equipment has been observed over the last 30 years. Improvement in production has been achieved with the help of large capacity earth moving machineries, continuous mining equipment, improved explosives and accessories, process innovations and increased application of information and computational technologies. These machineries involve high capital cost, and thus, the mining engineers should plan to achieve the best performance from these machineries. Performance of them, such as the excavating and transporting equipment, the crushers, etc. are largely influenced by the blast results, particularly, fragment size distribution and muckpile profile. Thus, proper blast design plays a vital role on the cost of the entire mining activities. In spite of introduction of continuous rock cutting equipment, drilling and blasting continue to dominate the production due to its applicability in wide geo-mining condition.

Therefore, to minimize the cost of production, optimal fragmentation from properly designed blasting pattern has to be achieved. Large fragments adversely affect the loading and hauling equipment and increase the frequency of sorting of oversize boulders and secondary blasting, thereby increasing the cost of mining. Similarly, fines are also undesirable as indicates excessive explosive consumption. It is, therefore, desirable to have a uniform fragment distribution, avoiding both fines and oversized fragments to optimize the overall cost of mining. In most of the surface mines, blast patterns are established through trial blasts. The blast pattern proposed from trial blast often fails to achieve the required blast results. Consequently, there is the necessity to develop a software for the design of surface blast based on successful blast researches implemented over the years.

2.2 OVERVIEW

Blasting is the second phase after drilling has been completed in the fragmentation process and can also be considered as the second most important process after drilling; as these two processes constitute the genesis of rock excavation for achieving a desired fragmentation and muckpile profile. Several factors affect the result of a blast and therefore, their design. These factors can be generally classified into two main groups. These are:

- Uncontrollable Factors or Variables
- Controllable Factors or Variables

2.3 UNCONTROLLABLE FACTORS

Uncontrollable parameters concerning blast design can be classified under the rock mass properties and the geological structure of the blast area and these parameters have to be considered in the blast design.

2.3.1 Properties of rock

A natural composite material; rock, is basically neither homogeneous nor isotropic. Inhomogeneity in rock is frequently discernible from its fabric, which includes voids inclusions and grain boundaries. Anisotropy is due to the directionally preferred orientations of the mineral constituents, modifications in the changing environments and characteristic of geological history, which may alter its behaviour and properties. The intrinsic environmental factors that influence drilling are geologic conditions, state of stress, and the internal structure of rock, which affect its resistance to penetration (Tandanand, 1973). The following parameters affect rock behaviour to drilling:

2.3.1.1 <u>Geology of the deposit</u>

The geology of any rock deposit can be classified basically based on its lithology, chemical composition and rock types.

- *Lithology:*

The lithology of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as colour, texture, grain size, or composition. It may be either a detailed description of these characteristics or be a summary of the gross physical character of a rock. It is the basis of subdividing rock sequences into individual lithostratigraphic units for the purposes of mapping and correlation between areas (Anon, 2012a).

- *Chemical composition:*

A main determining factor in the formation of minerals in a rock mass is the chemical composition of the mass, for a certain mineral can be formed only when the necessary elements are present in the rock. Calcite is most common in limestones, as these consist essentially of calcium carbonate; quartz is common in sandstones and in certain igneous rocks which contain a high percentage of silica.

Other factors are of equal importance in determining the natural association or paragenesis of rock-forming minerals, principally the mode of origin of the rock and the stages through which it has passed in attaining its present condition. Two rock masses may have very much the same bulk composition and yet consist of entirely different assemblages of minerals. The tendency is always for those compounds to be formed which are stable under the conditions under which the rock mass originated. A granite arises by the consolidation of a molten magma at high temperatures and great pressures and its component minerals are those stable under such conditions. Exposed to moisture, carbonic acid and other sub-aerial agents at the ordinary temperatures of the Earth's surface, some of these original minerals, such as quartz and white mica are relatively stable and remain unaffected; others weather or decay and are replaced by new combinations. The feldspar passes into kaolinite, muscovite and quartz, and any mafic minerals such as pyroxenes, amphiboles or biotite have been present they are often altered to chlorite, epidote, rutile and other substances. These changes are accompanied by disintegration, and the rock falls into a loose, incoherent, earthy mass which may be regarded as a sand or soil. The materials thus formed may be washed away and deposited as sandstone or siltstone. The structure of the original rock is now replaced by a new one; the mineralogical constitution is profoundly altered; but the bulk chemical composition may not be very different. The sedimentary rock may again undergo metamorphism. If penetrated by igneous rocks it may be recrystallized or, if subjected to enormous pressures with heat and movement during mountain building, it may be converted into a gneiss not very different in mineralogical composition though radically different in structure to the granite which was its original state (Anon, 2012b)

- *Rock types:*

According to Anon (2012c), rocks are generally classified by mineral and chemical composition, by the texture of the constituent particles and by the processes that formed them. These indicators separate rocks into three types: igneous, sedimentary, and metamorphic. They are further classified according to particle size. The transformation of one rock type to another is described by the geological model called the rock cycle.

2.3.1.2 Rock strength and properties

These are the mechanical properties affecting the rock.

- *Rock Density:*

Rock density is widely used as an indicator of the ease or difficulty to be expected in fragmenting rock. Denser rocks will require explosives with higher detonation pressures and higher powder factors, but will lend themselves to easier blasting, better fragmentation and displacement. The less dense rocks, on the other hand, require explosives with lower detonation pressure and lower powder factors.

- *Rock Porosity:*

It is the measure of the quantity of water-content, expressed as a percentage, in the rock formation. Generally, as the porosity of the rock increases its strength also decreases due primarily to the lowering of its tensile strength. The more porous rocks tend to absorb the explosive energy released into them, making desirable fragmentation and displacement rather difficult. Increased water content in the formation also increases the possibility of wet drillholes that would require the use of more expensive water resistant explosives with the resultant increased blasting costs. A classification of rock according to their density and porosity is shown in Table 2.1.

Table 2.1: Rock Classification according to Density and Porosity

Class	Dry Density (g/cm^3)	Density Description	Porosity (%)	Porosity Description
1	< 1.8	Very Low	> 30	Very High
2	1.8 – 2.2	Low	30 – 15	High
3	2.2 – 2.55	Moderate	15 – 5	Medium
4	2.55 – 2.75	High	5 – 1	Low
5	> 2.75	Very high	< 1	Very Low

(SOURCE: Bell, 1983)

- *Rock Strength:*

Rock strength properties (compressive and tensile) are used to classify rock types according to the ease or difficulty of mechanically penetrating the rock with a drill and fragmenting it with explosive energy. The compressive strength which is the measure of the static load that a rock sample can take until it fails or breaks is generally used as the standard for determining the drillability of the rock. The tensile strength, on the other hand, provides the standard for determining the blastability of the rock. A rule of thumb is that for any rock mass to be fragmented by an explosive charge its tensile strength must be exceeded by the energy of the explosive, otherwise the rock will not break. Rocks are variously classified according to their strength properties. Some of these are given in Tables 2.2 and 2.3.

Table 2.2: Compressive and Tensile Strengths of some Common Rocks

Rock Type	Compressive Strength (MPa)	Tensile Strength (MPa)
Granite	200 – 360	10 – 30
Diabase	290 – 400	19 – 30
Marble	150 – 190	15 – 20
Limestone	130 – 200	17 – 30
Sandstone	Approx. 300	Approx. 30

(SOURCE: Oloffson, 1988)

Table 2.3: Engineering Classification of Intact Rock on the Basis of Strength

Class	Description	Uniaxial Compressive Strength (MPa)
A	Very high strength	> 220
B	High strength	110 – 220
C	Medium strength	55 – 110
D	Low strength	27.5 – 55
E	Very low strength	< 27.5

(SOURCE: Budavari, 1983)

- *Rock Hardness:*

According to Anon (2010), hardness or brittleness of rocks has a significant effect on blast results. Soft rock is much easier to handle than hard rock. For example, if soft rock is undercharged and blasted it would probably just heave and there would not be any appreciable throw, but would still be diggable with loading machinery. Should this, soft-rock, however, be somewhat overcharged excessive throw rarely occurs.

Hard rock, on the other hand, when undercharged would produce tight and blocky muck pile that is very difficult to dig and cause excessive wear on the excavating machinery. If this same hard rock is overcharged, the result would most likely be excessive and undesirable flyrock and airblast. Designing blasts for hard rock therefore requires closer control than for soft rock. It may require smaller burdens, closer drilling patterns, less stemming and greater quantity of explosive charge.

- *Rock Variability:*

Variability or degree of variation of rock properties is important to blasting because knowledge of it helps in predicting the spread or variation of the fragmentation in the blasted material. This is due to the fact that most rocks are neither homogenous nor isotropic so that when one, for example, takes a highly anisotropic or inhomogeneous rock, one would expect a wide variation or spread in the fragmentation results when blasted. This situation would therefore necessitate a careful study of the fragmentation requirements when the specific blast is being designed (Anon, 2010).

2.3.1.3 Structural geology

According to Yomekpe-Agbeno (2008), rock structure describes the nature and the extent of gross discontinuities, such as bedding changes, joints, faults, fractures, fissures, voids or cavities, mud seams and generally, zones of weakness which are encountered in rock formations. In most surface blast situations, especially in open pit blasts, these discontinuities present a lot of problems for drilling and blasting operations and therefore have great effect on the resulting fragmentation. They provide channels through which compressed air energy is dissipated, causing such problems as reduction in drill penetration rate or drill bits and rods getting stuck in the drillholes.

2.3.1.4 Presence of water

Depending on the source and quantity, it may be an uncontrollable or a controllable factor. These factors also influence the blast design parameters and the fragmentation produced; thus their effects to blasting need to be quantified

2.3.2 Rock factor

An attempt to quantify the effect of rock parameters on fragmentation was made by Cunningham (1987), who used Lilly's (1986) "blastability index A", and incorporated it in his popular Kuz-Ram model (Cunningham, 1983). Table 2.4 shows a generalized rock category with the corresponding rock factors. He discussed that every assessment of rock for blasting should at least take into account the density, mechanical strength, elastic properties and fractures. He defined the rock factor A as;

$$A = 0.06 \cdot (RMD + JF + RDI + HF) \tag{2.1}$$

Where:

RMD (Rock mass description): *10 if powdery or friable, = JF if vertically jointed, 50 if massive rock*

JF (Joint Factor): *Joint Plane Spacing term (JPS) +Joint Plane Angle term (JPA)*

JPS = 10 if the average Principal Mean Spacing (PMS) <0.1 m; 20 if 0.1 < average PMS < 1 m; 50 if average PMS>1 m.

JPA = 20 if dipping out of face; 30 if striking perpendicular to face; 40 if dipping into face

RDI (Rock Density Influence) = $0.025 \cdot \rho_r - 50$; *(kg/m^3)*

HF (Hardness factor) = $\frac{E}{3}$ *if E<50, or* $\frac{UCS}{5}$ *if>50, depending on uniaxial compressive strength UCS (MPa) or Young's Modulus E (GPa).*

ρ_r = Rock Density

Table 2.4: Rock factor values for rock categories

General Rock Category	Rock Factor (A)
Hard, weakly fissured rock	13
Hard, heavily fissured rock	10
Medium to Hard rock	7
Weak rock	4
Extremely weak rock	1

(SOURCE: Konya and Walter, 1990)

2.4 CONTROLLABLE GEOMETRICAL FACTORS

These are factors over which the blaster can exercise control and therefore can balance them in their selection to achieve the desired results. For the purpose of blast design, the controllable factors can be categorised into the following groups;

- Geometric parameters which includes the parameters for the bench and blast geometry such as the drillhole diameter, burden, bench height, just to mention a few.
- The physicochemical parameters which are the parameters pertaining to the explosive such as the powder factor, type of explosive, strength of explosive, primer used, etc.
- The time parameter which talks about the type of initiation, the detonation type and the initiation sequence employed in a blast.

2.4.1 Bench height

The bench height is the vertical distance between each horizontal level of the pit and can also be defined as the vertical distance between the crest and the toe of the bench. Unless geologic conditions dictate otherwise, all benches should have the same height. The height will depend on the physical characteristics of the deposit; the degree of selectivity required in separating the ore and waste with the loading equipment; the rate of production; the size and type of equipment to meet the production requirements; and the climatic conditions. The elements of the bench are illustrated in the Figure 2.1 below. The bench height should be set as high as possible within the limits of the size and type of equipment selected for the desired production however it should not be so high that it will present safety problems. According to Yomekpe-Agbeno (2008), in estimating the desired bench height of a given operation, a rule of thumb gives a relation of the blast diameter and the bench height.

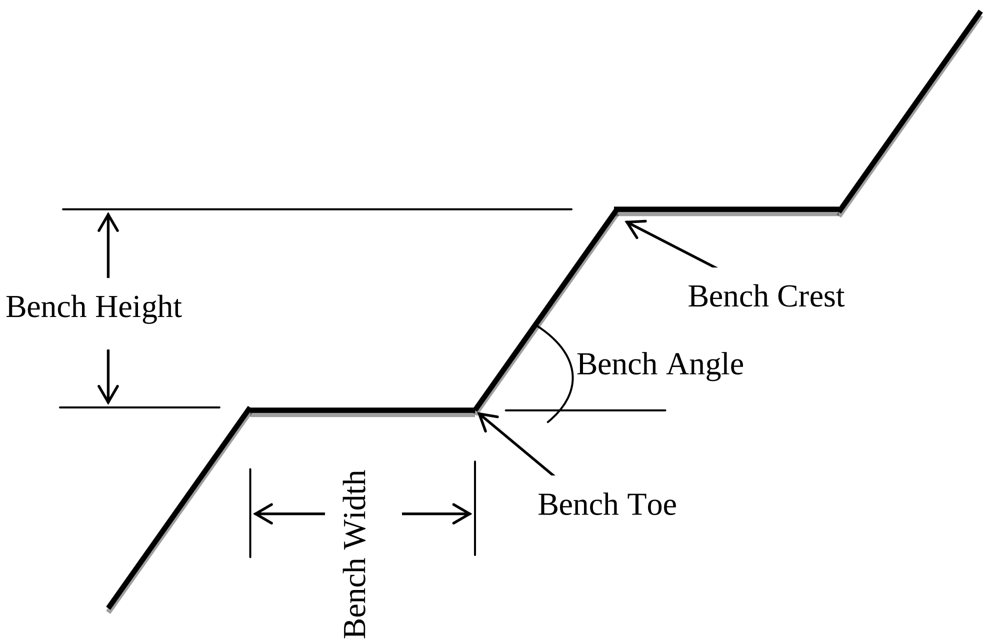


Figure 2.1: Cross section of a practical bench face

2.4.2 Drillhole diameter

The drillhole diameter is selected such that, in combination with appropriate positioning of the holes, it will give proper fragmentation suitable for loading, transportation equipment and crusher used. Although Yomekpe-Agbeno (2008) states that a blast designer does not have the freedom to select his own drill bit size because this is usually fixed by the available drilling equipment on the mine, Jimeno *et al.* (1995) adds to the assertion made by Yomekpe-Abgeno (2008) that the ideal drilling diameter for a given operation depends not only on the capacity of the loading equipment but upon the following factors:

- Properties of the rock mass to be blasted
- Degree of fragmentation required
- Height of bench and configuration of charges
- Cost of drilling and blasting

The drilling and blasting will become economical with increase in diameter. When the drillhole diameter is increased and the powder factor remains constant, the large drillhole pattern gives coarser fragmentation. This problem can be overcome by keeping burden unchanged and elongating spacing. When joins or bedding plane divide the burned into larger blocks or hard boulder lie in a matrix of softer strata, acceptable fragmentation is achieved only when each boulders has a drillhole which necessitates the use of small diameter drillholes. Hole diameter varies from 35 mm in small benches up to 440 mm in large benches (Partha, 2010).

2.4.3 Drillhole inclination

The hole inclination of a blast can be basically defined as the angle, normally measured to the vertical, to which a drillhole is drilled and it should not go beyond 30 degrees. According to Jimeno *et al.* (1995) the benefits of inclined drilling are better fragmentation, displacement and swelling of the muck pile, less subdrilling and better use of the explosive energy, lower vibration levels and less risk of toe appearance. The disadvantages of inclined holes are the following:

- Increased drilling length and deviation when drilling long drillhole.
- More wear on the bits, drill steel and stabilizers.
- Less mechanical availability of the drilling rig.
- Poor flushing of drill cuttings due to friction forces, requiring an increase in air flow.

Jimeno *et al.* (1995) further explains that there are few management factors which are disadvantageous with the inclined holes and are as follows:

- Difficulty in positioning of the drills.
- Necessity of close supervision which creates work lapses.
- Lower drill feed; which means that in hard rock, the penetration rate is limited in direct proportion to the angle of inclination of the mast.
- Less productivity with rope shovels due to lower height of the muck pile.
- Problems in charging the explosive, especially in drillholes with water.

2.4.4 Subdrill

Subdrilling is the depth to which a drillhole will be drilled below the proposed grade line or floor level to ensure that breakage will occur to the grade line. Its primary function is to assure that the full face of rock or bench can be removed to the desired limits of the excavation without leaving any toes or frozen ground.

The actual amount of subdrilling needed depends on the burden distance, orientation of drillhole relative to all open faces and the geological structural at its bottom. The subdrill of a blast should normally range between 0.3 and 0.5 times the burden. Excessive subdrill wastes drilling and explosives, cause intensified ground vibration and result in fractured gouged pit floor (Temeng, 2010).

2.4.5 Stemming

Stemming refers to the process of filing the top portion of the drillhole, where there are no explosives, with inert material to confine the explosive gases. Examples of stemming materials are sand, chippings, tailings from treatment plants or mills and these stemming materials can be used with or without stemming plugs which helps in allowing maximum confinement of the explosive gases and high blast efficiency. The main functions for stemming include (Yomekpe-Agbeno, 2008):

- Prevents the premature escape of gases by giving some confinement to the explosive gases, thereby reducing the incidence of flyrock and airblast or incidence of blown-out shots.

- Allows adequate gaseous build-up which is an important factor in obtaining adequate rock fragmentation.

The amount of stemming is dependent on the prevailing conditions at the bench and it is a direct function of the burden. The optimal stemming length is influenced by factors such as rock conditions, hole diameter, explosive strength and density, charge length, flyrock control and bench height. It is therefore important to select a stemming that will give desirable fragmentation and prevent the adverse effects of blasting such as ground vibration, flyrock and airblast.

2.4.6 Burden

Burden is considered the most important and critical variable in the design of a surface blast. There are actually two types of burden; drilled burden and shot burden. Drilled burden can be defined as the distance between a role of holes and the nearest free face and it is usually measured perpendicular to the role of holes. It can also be defined as the distance between two rows of holes. Shot burden is defined as the distance between the hole that is detonating and the nearest free face developed during the blast.

Morhard (1987) states that for a given rock type, explosive and drillhole spacing, there is an optimal burden dimension which depends upon a combination of variables including the drillhole diameter, the drillhole depth, the spacing between drillholes, the milliseconds delay pattern, the explosive used, the rock mass characteristics, the degree of fragmentation and the muck pile shape sought. He further states that too small burden dimension can lead to flyrocks, escape of detonation gases into the atmosphere in the form of noise and airblast which are also signs of the inefficient use of the explosives' energy. However, too large burden results in gases being confined in the hole for a time interval longer than desired which results in poor fragmentation, higher ground vibrations, excessive back-break, toe and uneven floor.

2.4.7 Spacing

Spacing represents the distance between holes in a row. Hemphill (1981) defines spacing as the distance between drillholes fired on the same delay or greater delay in the same row. Spacing is calculated as a function of the burden. The spacing of any blast can also be defined as a function of the stiffness ratio (Assakkaf, 2003) and it varies in relation to the burden with varying stiffness ratio and according to Morhard (1987), spacing in production blast should range between 1 and 1.8 times the burden.

Spacing that are significantly less than the burden tend to cause early stemming ejection and premature splitting between drillholes. These effects encourage rapid release of gases to the atmosphere and result in noise and airblast. Conversely, when the spacing is too large, the rock may be inadequately fragmented between holes, leaving an uneven floor (Morhard, 1987).

Figure 2.2 shows the various controllable parameters explained above.

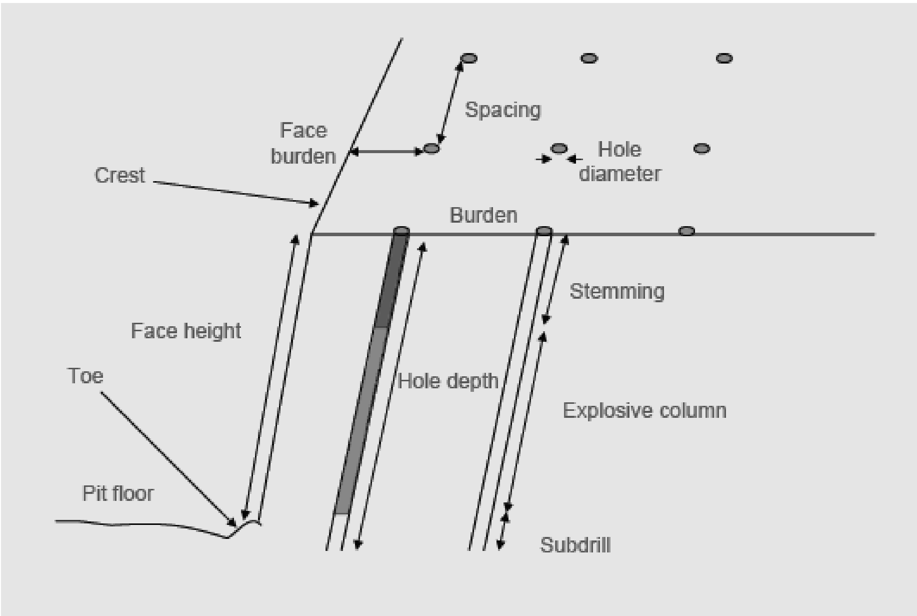


Figure 2.2: Cross section of a bench showing the various bench parameters

(SOURCE: Anon, 2012d)

2.4.8 Powder factor

Powder factor is defined as the ratio of the explosive mass to the volume of material blasted. It can also be defined as the amount of explosive needed to fragment a tonnage of rock. Powder factor can be classified as total powder factor or powder factor above grade in relation to the subdrill. The total powder factor which is mostly used includes the material in the subdrilling zone in the calculations because it basically describes the amount of work that the explosive is supposed to accomplish whiles the powder factor above grade does not take into consideration the material in the subdrilling zone.

According to Jimeno *et al.* (1995) the powder factor is not the best and only tool used to design the blasts unless it is referring to a pattern explosive or is expressed as energetic consumption, basically because the spatial distribution of the explosive charges within the rock mass has great influence upon the results of the blasts.

2.5 EXPLOSIVE CRITERIA

An explosive is a compound or mixture which is capable of undergoing extremely rapid decomposition, thereby releasing substantial amounts of heat and gas at a high pressure. According to Yomekpe-Agbeno (2008), an explosion can be broken down into four phases:

- release of gas,
- intense heat,
- extreme pressure; and
- the explosion.

When an explosive is detonated, gas is released and as the temperature of the gas increases, the pressure also increases, according to Charles' law. Therefore, when an explosive is detonated in a drillhole, the pressure exerted against the walls of the drillhole will move and break the rock, the degree of breakage depending on the amount of pressure exerted by the explosive (Hemphill, 1981).

2.5.1 Types of Explosives

The explosive used as the main borehole charge can be broken up into three categories.

- Nitro-glycerine-based explosives (Dynamites or gelatine).
- Water-based or Wet Blasting Agents (Slurries and Emulsions).
- Ammonium Nitrate-based (ANFO).

2.5.1.1 Nitro-glycerine-based explosive

In Sweden in 1867, Alfred Nobel discovered how to create dynamite. Most dynamites are nitro-glycerine based. Being the most sensitive of all explosives used; dynamite is more susceptible to accidental initiation. There are two major subclasses of dynamite, Granular dynamite and gelatine dynamite. Granular dynamite is a compound which uses nitro-glycerine as its explosive base. Gelatine dynamite uses a mixture of nitro-glycerine and nitrocellulose which produces a waterproof compound.

2.5.1.2 <u>ANFO</u>

Dry blasting agents are the most widely used explosive used in the world. ANFO is the most common dry blasting agent. An oxygen balanced mixture of ANFO is the lowest cost source of explosive energy today. To increase energy output, ground aluminium foil is added to dry blasting agents. A downfall of this however, is that the cost is increased.

Two categories make up dry blasting agents: cartridge blasting agents and bulk ANFO.

- Bulk ANFO is either blown or augured into a drillhole from bulk truck. These blasting agents will not function properly if placed in wet holes for extended periods of time.
- Cartridge blasting agents however, are made for use in wet blasting holes. Cartridge blasting agents are available with densities that are greater than that of water if you would like them to sink, or less than that of water if you would like them to float.

2.5.1.3 <u>Wet blasting agents</u>

Blasting agents that contain more than 5% water by weight are referred to as wet blasting agents. Within this category are:

- water gels or slurries,
- emulsions, and
- heavy ANFO.

- *Slurry Explosives:*

Slurry explosives, also called water gels, are made up of ammonium nitrate partly in an aqueous solution. Depending on the rest of the ingredients slurries can be classified as a blasting agent or an explosive. Slurry blasting agents contain non explosive sensitizers or fuels such as carbon, sulphur, or aluminium. These blasting agents are not cap sensitive. On the other hand slurry explosives contain cap- sensitive ingredients such as TNT and the mixture itself may be cap sensitive. The slurries are thickened and stabilized with a gum, such as guar gum. This gives them very good water resistance. “Slurry boosting” is practiced when slurry and a dry blasting agent are used in the same borehole. Most of the charge will come from the dry blasting agent. Boosters placed at regular intervals may improve fragmentation. The disadvantages of slurries include higher cost, unreliable performance, and deterioration with prolonged storage.

- *Emulsions:*

An emulsion is a water resistant explosive material containing substantial amounts of oxidizers, often ammonium nitrate, dissolved in water and forming droplets, surrounded by fuel oil. The droplets of the oxidizer solution are surrounded by a thin layer of oil and are stabilized by emulsifiers. To achieve the required sensitivity within the emulsion voids are added. These voids may include small gas bubbles or micro-spheres made out of glass.

Sensitivity of an emulsion decreases as the density increases. The density and strength of an emulsion can be adjusted by adding products such as powdered aluminium, gassing agents (to reduce density), etc. It is therefore necessary to work above the critical diameter and use powerful initiators. If the emulsion is not cap sensitive it is considered a blasting agent.

Emulsions have high energy, reliable performance, excellent resistance to water, and relative insensitivity to temperature changes. The direct cost of an emulsion explosive is higher but this is offset by time saved in loading and a reduction in nitrate content of broken muck. Some other advantages to using emulsions in rock blasting include: a lower cost, excellent water resistance, high detonation velocities, and it is very safe to handle and manufacture.

- *Heavy ANFO:*

Heavy ANFO is a product comprised of up to 45 to 50% ammonium nitrate emulsion mixed with prilled ANFO. It was developed in an attempt to increase the bulk density of ANFO. The only fuel component is in the ANFO (or a liquid fuel), while the emulsion contain no solid fuel, making the mixture a "repumpable" consistency. The final product has improved strength and provides good water resistance in comparison to ANFO, with a price range between that of ANFO and emulsion.

Heavy ANFO is made up of mixtures of ammonium nitrate prills, fuel oil, and slurries or emulsion. The main advantage of heavy ANFO is that they can be mixed at the drillhole and quickly loaded into a hole. The ratio of the amount of slurry mixed with the ANFO can be changed to offer either a higher energy load or a load which is water resistant. The cost of heavy ANFO rises with increasing amount of slurry. These have an advantage over cartridge blasting agents because they fill the entire drillhole with energy and have to wasted volume that would occur with cartridges.

2.5.2 Explosive properties

According to Yomekpe-Abgeno (2008), the properties of explosives that will help a blast engineer to select the appropriate explosive to achieve desired fragmentation include the following:

- Velocity of Detonation, VOD
- Density
- Detonation Pressure
- Drillhole Pressure
- Sensitiveness
- Sensitivity
- Strength and Energy Output
- Water-Resistance

2.5.2.1 *Velocity of Detonation, VOD*

This is the speed at which the detonation front travels through the column of explosive. Velocity of detonation is important in determining explosive functioning and performance. It generally varies between 2000m/s and 7500m/s for most commercial high explosives when confined; but when tested under unconfined conditions the value would only be 75% of the confined value (Yomekpe-Agbeno, 2008). For an explosive to effectively fragment rock its VOD must exceed the seismic velocity of the rock being blasted, whereby the explosive shock waves create adequate tensile stresses responsible for the fragmentation.

Explosives with high VODs are more favourable in hard rock, whereas in softer materials explosives with lower VODs give better results. Generally, lower VOD explosives tend to release gas pressure over a longer period of time than explosives with higher VODs. As a result, an explosive with a low VOD has more heave.

2.5.2.2 *Density*

The density of an explosive may be defined as its specific weight expressed as mass per unit volume (g/cm^3), or its weight per unit volume or its specific gravity. The practical importance of the explosive density to the blast engineer is in the determination of the charge weight per unit length of hole referred to as loading density and expressed as kg/m or lb/ft of hole length.

Additionally, the importance of the explosive density may be found in its effect on the following:

1. The buoyancy of the explosive cartridge in wet holes. The cartridge may or may not sink.
2. Energy concentration in drillholes. Given certain weight strength of an explosive, a high density enables the maximum amount of energy to be packed into the drillhole, and allows for considerably wider spaced drilling patterns. The overall effect is that unit costs of drilling will be minimized with increased drill productivity.

2.5.2.3 Detonation Pressure

The detonation pressure is the pressure in the reaction zone behind the detonation front at the Chapmen-Jourquet (C-J) plane when the explosive is detonated as shown in Figure 2.3. It is often measured in kilo bars

The detonation pressure is a significant indicator of the ability of an explosive to produce the desired fragmentation in a well-consolidated burden. It is also an important character an explosive must have if it is to be used as a primer.

2.5.2.4 Drillhole Pressure

Drillhole or borehole pressure is the pressure exerted on the walls of the drillhole by the expanding gases of detonation after the completion of the chemical reaction. It is also sometimes called explosion pressure. It is a function of confinement of the explosive, and the quantity and temperature of the gases of detonation. It is generally considered as one factor that plays the dominant role in breaking most rock and in displacing all types of rocks encountered in blasting.

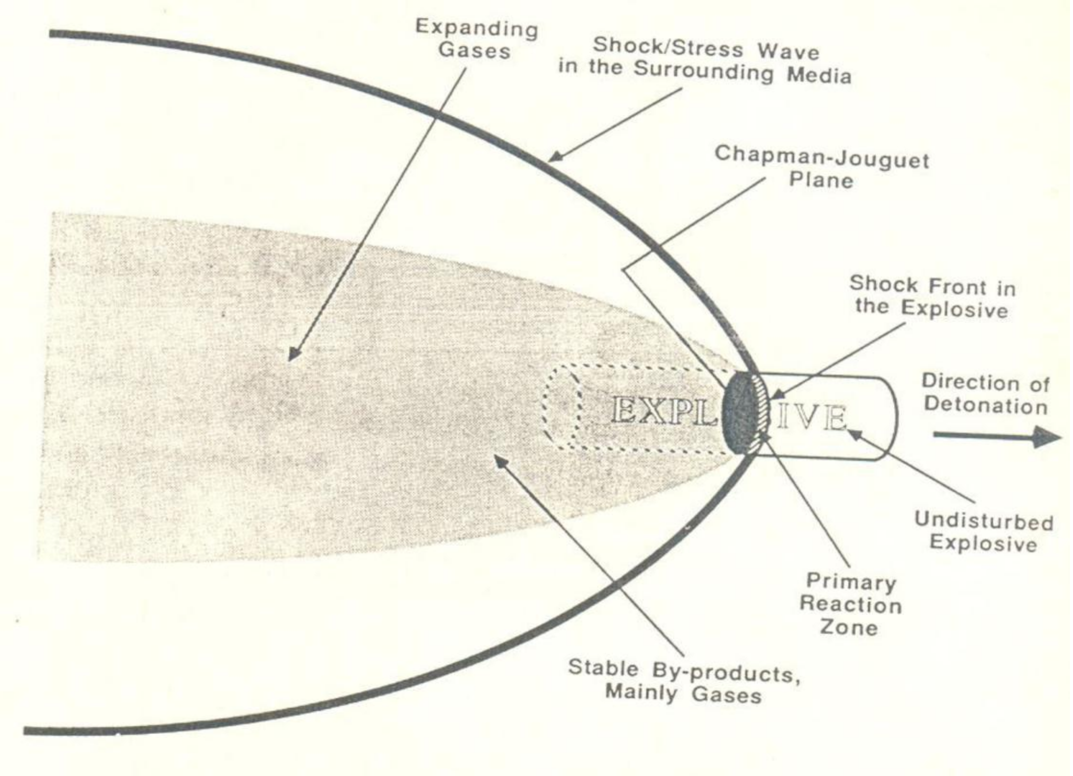


Figure 2.3: Illustration of detonation

(SOURCE: Yomekpe-Agbeno, 2008)

2.5.2.5 Sensitiveness

Sensitiveness of an explosive may be defined as the capability of that explosive to propagate detonation once it has been initiated. The length of the air-gap over which a "donor" cartridge will detonate a "receptor" cartridge under unconfined conditions determines it. This is an important property to be considered when selecting an explosive, because if sensitiveness is low there can be interruptions or failures in the detonation if the column of explosive is not continuous. If, on the other hand, the sensitiveness is too high there is the likelihood of "cross" or "sympathetic" propagation between adjacent holes spaced too closely together or where the formation is badly fractured and faulted. One major effect of such "sympathetic" propagation is that where millisecond delay patterns are used their desired influence is eliminated, resulting in poor fragmentation, excessive airblast and ground vibration.

2.5.2.6 Sensitivity

Sensitivity of an explosive is its susceptibility to initiation. It is a measure of how safe an explosive lends itself to handling. Generally explosives that require larger or stronger primers have low sensitivity and are therefore less susceptible to accidental initiation and hence safer to handle. A substance may be classified as an explosive if it is cap sensitive such as the dynamites. If however, the substance is not cap sensitive it is classified as a Blasting Agent, and includes the ANFOs, emulsions, slurries and the water gels.

2.5.2.7 Strength and Energy Output

The strength of explosive is in most cases expressed as a percentage of the strength of blasting gelatine. It may be expressed either as weight strength or volume or bulk strength. The strength of an explosive can also be expressed as an absolute or as a relative number, thus Absolute Weight Strength (AWS); Absolute Bulk Strength (ABS); Relative Weight Strength (RWS) and Relative Bulk Strength (RBS). Blasting gelatine was chosen as the standard when nitro-glycerine was the principal energy-producing ingredient in explosives. However, lately manufacturers have been using calculated energy values to compare the strengths of explosives. ANFO is now used as a base or standard because blasting gelatine has been superseded by ANFO as the most widely used explosives in the world today.

For bulk loading, the diameter of the explosive refers to the borehole diameter, and for cartridge loading it refers to the diameter of the cartridge.

Explosive energy is released into the surrounding rock in two different forms:

- detonation or shock pressure, and
- borehole or drillhole pressure.

The detonation or shock pressure exerts a fragmenting force on the rock, while the borehole pressure is due to the gas build-up and is primarily responsible for displacement of the rock.

2.5.2.8 Water-Resistance

This is the ability of the explosive to withstand exposure to water without losing its sensitivity and efficiency. It is dependent on the packing as well as its inherent ability to repel water.

The gelatinous explosives such as the dynamites, the slurries and emulsions have good water-resistant properties and are therefore suitable for all drillhole conditions. The other explosives such as ANFO, on the other hand, have poor water resistant properties and are unsuitable for wet drillhole conditions. Such explosives will dissolve in water and loose their efficacy.

2.6 ENVIRONMENTAL EFFECTS OF BLASTING

The main aim of blasting is to produce an adequate rock fragmentation size at a relatively minimum cost. However in the process of venting of the explosive energy in the rock formation, adverse effects are produced on the environment and lives. These side effects result as to whether the blast is properly designed and executed or not, taking into consideration the controllable and uncontrollable blast parameters. The difference between a good and a bad blast however depends on the magnitude of the blast output and consequently, the degree of actual damage occurrence. The output of a blast includes:

- Flyrocks
- Ground vibrations
- Airblast

2.6.1 Flyrock

There are two main types of movement that can occur, these are;

- Forward movement of the entire rock mass which is mainly horizontal and is dependent on the specific charge and rarely presents any hazard in the blasting operation.
- Flyrock which is a scatter from the rock surface and the front of the blast.

Flyrock may be defined as the rocks propelled from the blast area by the force of an explosion. They tend to travel long distances and are normally the main cause of on-site fatalities and damage to equipment. These are mainly caused by improperly designed or improperly executed blasts; often a result of incompetent rock, where the gases may break through easily due to less resistance than in the more competent parts of the rock (Yomekpe-Agbeno, 2008).

2.6.2 Ground vibration

When a blast is detonated, some of the energy travels through the ground and rock mass as vibration. The ground vibration travels through the rock mass at varying speeds depending upon the density and thickness of the geology. Although perceptible, the energy level decreases rapidly with distance. To the blaster, vibration represents wasted explosive energy.

Blasting seismographs measure ground vibrations in terms of particle velocity. Particle velocity is measured in mm/s. Ground vibrations are mainly controlled by limiting the pounds of explosives detonated per delay interval.

2.6.3 Airblast

Airblast is a change in air pressure caused by blasting. When a blast is detonated, some of the energy is vented into the atmosphere through the fractures in the rock or through inadequate stemming material. However, the upward or outward movement of the rock from the blast is the main source of airblast. Due to the frequency content, airblast cannot be effectively heard by the human ear. Airblast travels at the speed of sound and can be influenced by wind and temperature inversions.

Airblast is also measured with a blasting seismograph equipped with a microphone. The most common units to measure airblast is decibels (dB) which is a logarithmic sound-pressure scale related to human hearing. It is also common to report peak over pressure in Pascal (Pa).

Airblast is controlled by properly confining explosive charges in the borehole. This is accomplished by using adequate stemming material and by not loading explosives into weak zones in the rock. Airblast also represents wasted explosive energy. If the explosive gases escape from the drillhole, there will not be adequate energy to fragment the rock.

3 THEORIES OF BLAST DESIGN

3.1 INTRODUCTION

In order to examine the existing practices in blasting, it is desirable to study previous records of blast designs from different researchers. A critical review of the blasting practices will help in identifying the shortcomings and exploring the possibility of improving the blast results, by introducing modified techniques and updated products. Some of the important concepts including empirical equation supporting blast design proposed by different researchers are discussed below.

3.2 BLAST DESIGN THEORIES

3.2.1 Allsman and Speath (1960)

Allsman (1960) and Speath (1960) proposed an equation based on the following parameters:

$$B=\left(\frac{K\cdot De}{12}\right)\cdot\left(\frac{Pe}{S_t}\right)^{0.5} \tag{3.1}$$

Where:

K: constant = 0.8 for most rock

De: diameter of explosive (m)

Pe: detonation pressure

S_t: rock tensile strength

The difficulty in using this equation however was that the borehole pressure and the tensile strength of the rock mass were not readily available and it also indicated that the burden was linear with the charge diameter.

3.2.2 Ash (1963)

Ash (1963) published a burden equation for use in surface blasting which combined some of the variables into adjustable constants.

$$B=\left(\frac{K_b \cdot De}{12}\right) \tag{3.2}$$

Where:

B: burden (feet)

K_b: burden constant

De: diameter of explosive (inches)

The equation was simple to use and it related burden to some constant number multiplied by the charge diameters. The article defined ranges of constant s to be used based on the explosive and rock types. That is, Ash (1963) integrated the borehole pressure with the tensile strength relationship and therefore the blaster did not have to predetermine these difficult-to-obtain values.

3.2.3 Ash (1968)

Ash (1968) proposed a method to adjust the constant K_b in the burden calculation of his previously proposed burden formula by using the velocity of detonation of the explosive squared times the density of the explosive. This method of adjustment seemed to work reasonably well in midrange; however, at both ends of the velocity range, the compensations in burden were extreme.

3.2.4 Konya (1972)

According to Konya and Walter (1990), Konya in 1972 proposed a burden equation similar to the Ash (1968) equation.

$$B = 3.15 \cdot De \cdot \left(\frac{\rho_e}{\rho_r}\right)^{0.33} \tag{3.4}$$

Where:

B: burden (feet)

De: explosive diameter (inches)

ρ_e: specific gravity of explosive

ρ_r: specific gravity of rock

In this equation, the constant could be adjusted by using the ratio of the specific gravity of the explosive divided by the specific gravity of the rock, both raised to the one-third power. This approach gave near identical values in the midrange of the Ash (1968) equation; however, both ends of the range were more accurately defined (Konya and Walter, 1990). Although this equation functioned well as a first approximation, field personnel's found it difficult to work with a relationship which contained a quantity raised to the 0.33 power.

3.2.5 Langefors and Kihlstrom (1978)

Langefors and Kihlstrom (1978) demonstrated from laboratory model scale tests that ratio exceeding three for simultaneously fired charges in a single row gave their fragmentation. This was observed by reducing the conventionally used burden. For the same model tests with multiple rows of charge fired together, but rows of holes delayed relatively resulted in good fragmentation, effective stem wall friction and improved stem performance.

$$B_{max} = \frac{D}{33}\sqrt{\frac{\rho_e \cdot E}{Co \cdot f \cdot \frac{S}{B}}} \qquad (3.3)$$

Where:

B_{max}: maximum burden (m)

D: drillhole diameter (m)

ρ_e: explosive density in the borehole (kg/m^3)

E: Swedish strength relative to the Swedish dynamite (LFB) f: degree of confinement of drillhole

$\frac{S}{B}$: spacing to burden ratio

C_O: corrected rock factor (kg/m^3)

3.2.6 Jimeno (1980)

Jimeno (1980) as referenced from Jimeno *et al.* (1995) also modified Ash (1968) equation by incorporating a seismic velocity to the rock mass resulting in

$$B = 0.76 \cdot D \cdot F \tag{3.5}$$

Where:

B: burden (m)

D: Drillhole diameter (inches)

F: correction factor based on rock type = Fr · Fe

$$Fr = \left[\frac{2.7 \cdot 3500}{\rho_r \cdot V_r}\right]^{0,33} \tag{3.6}$$

$$Fe = \left[\frac{\rho_e \cdot {V_r}^2}{1.3 \cdot 3660}\right]^{0,33} \tag{3.7}$$

Where:

ρ_r: specific gravity of rock (g/cm^3)

V_r: seismic propagation velocity of the rock mass (m/s)

ρ_e: specific gravity of the explosive charge (g/cm^3)

V_d: detonation velocity of explosive (m/s)

3.2.7 Konya and Walter (1990)

Konya and Walter (1990) proposed another burden equation, which would give similar results to these using his earlier burden formula. This new equation was simple to use, required no power functions and was ideally suited for field use.

$$Bc = \left[1.5 + \frac{2 \cdot \rho_e}{\rho_r}\right] \cdot D_e \qquad (3.8)$$

Where:

Bc: calculated burden (ft)

ρ_e: density of explosive

ρ_r: density of rock

D_e: diameter of explosive (in)

No one number will suffice as the exact burden in a particular rock-type because of the variable nature of geology. Even when strength characteristics are unchanged, the mode of rock deposition and geologic structure must also be considered in the blast design. Konya and Walter therefore, to incorporate the heterogeneity of the rock in order to give a more practical value multiplied the calculated burden by certain factors as shown below;

$$B = Bc \cdot K_d \cdot K_s \qquad (3.9)$$

Where:

B: practical burden (ft)

Bc: calculated burden (ft) through Equation 3.8

K_d: correction factor for rock deposition; as shown in Table 3.1

K_s: correction factor for rock structure; as shown in Table 3.2

Table 3.1: Correction factor based on rock deposition

Rock Deposition	**K_d**
Bedding steeply dipping into cut	1.18
Bedding steeply dipping into face	0.95
Other cases of deposition	1.00

(SOURCE: Konya and Walter, 1990)

Table 3.2: Correction factor based on rock structure

Rock Structure	**K_s**
Heavily cracked, frequent weak joints, weakly cemented layers	1.30
Thin, well-cemented layers with tight joints	1.10
Massive intact rock	0.95

(SOURCE: Konya and Walter, 1990)

3.3 FRAGMENTATION ANALYSIS

There are several methods and several theories to calculate the average fragmentation size of a drillhole, among this are the popular Kuz-Ram Model, the model developed by *Julius Kruttschnitt Mineral Research Centre* (JKMRC) and the Kuznetsov-Cunningham-Ouchterlony (KCO) Model. However, the study studies only the Kuz-Ram Model which is the most common and widely used model for fragmentation analysis of blasted rocks.

3.3.1 Kuz-Ram model

The most known empirical model is the Kuz-Ram model (Cunningham, 1983, 1987). It is the most widely used approach for the prediction of rock fragmentation. This model does not simulate the fracture growth by gas or waves, but simply uses blast design and rock factors in an empirical equation to predict the fragmentation size distribution. The fragmentation prediction results show good correlation with results from numerical models and the Kuz-Ram model is therefore a relative simple and fast fragmentation prediction tool.

- Timing effect,
- Lack in prediction of fines.

There are some models that are proposed to improve the Kuz-Ram's model's inability to predict the fragment size distribution. These models; being the crush zone model (CZM) and the two component model (TCM) together form the JKMRC model, which will be described later. Experiences shows, that the Kuz-Ram model predict the coarse part of the fragmentation size distribution with good accuracy (Djordjevic, 1999; Cunningham, 1987)

The unique feature of Kuz-Ram model is that the input data consist of the relevant blast design parameters which have been explained earlier. The key equations are the backbone of this model:

- Kuznetsov's equation
- Rosin-Rammler's fragment size distribution

3.3.1.1 Kuznetsov's Equation

With respect to the Kuznetsov's, it was created by Kuznetsov and further developed by Cunningham. Kuznetsov (1973) put it as a breakage theory which talks about the fact that the amount of breakage that occurs with a known amount of explosive energy can be estimated by the use of the equation;

$$x_{50}=A \cdot q^{-0.8} \cdot Q^{0.167} \cdot \left(\frac{E}{115}\right)^{-0.633} \qquad (3.10)$$

Where:

x_{50}: medium fragment size (cm)

q: powder factor (kg/m^3)

Q: mass of explosive charge per hole (kg)

E: relative weight strength of explosive (ANFO= 100)

A: blastablity index or rock factor constant; calculated through Equation 2.1

4 DATA ANALYSIS

4.1 INTRODUCTION

With the continued evolution of drilling equipment, and the extension of surface mining, bench blasting is fast becoming the most popular method of rock fragmentation with explosives Jimeno *et al.* (1995). In the application of explosives, it is only possible to describe the various practices that have developed in term of generalities. The particular conditions at a site will normally dictate details of the surface blast design. Typical considerations are hole diameter, water conditions, burden, bench height, rock structure and, of course, the type of explosive used. Due to the high heterogeneity of rocks with peculiar properties such as concealed faults, caves and rock formation changes, amongst others, it is important to note that these properties will have a significant effect on the blasting results even with the blast designed by the most experienced blaster. This surface blast design software, like all other blast designs proposed by various blasters and researchers, tries to reflect on the changes at a mine site by the manipulation of various variables that influence blasting with the main aim of creating the most favorable blast condition for the efficient use of the explosive energy and thereby reducing blasting cost.

4.2 DESIGNING THE BLASTING PARAMETERS

Bench blasting in this research work is classified using the drillhole diameter. Basically, there are two classes of drillhole diameter and these are;

- small diameter blasting, and
- large diameter blasting.

According to Jimeno *et al.* (1995), small diameter blasting have drillhole diameters ranging from 65 mm to 165 mm and are normally seen in quarries and small mines whiles large diameter blasting which can have drillhole diameter ranging above 165 mm up to 450 mm are mostly seen in large mine production sites. In small diameter blasting, the Swedish technique developed by Swedish researchers is used while in large diameter blasting, the Konya formula is used.

Three types of explosives are also considered in the research. These are generalized into;

- ammonium nitrate-based explosives (ANFO),
- aqueous blasting agents (emulsions), and
- nitro-glycerine or cartridge based explosives (dynamites or gelatine).

4.2.1 Burden

For small diameter blasting, the Swedish method (Gustafson, 1973) is used. It has been modified as follows:

$$B = (0.041 \cdot D_e) - (0.05 + (0.03 \cdot \frac{H}{\cos\beta})) \quad (4.1)$$

Where:

B: Practical burden (m)

L: Drillhole length (m)

D_e: Diameter of explosive (mm)

For large diameter blasting, the Konya formula (Konya and Walter, 1990) as shown in Equation 3.8 is used.

Since rocks are not homogeneous, Konya and Walter proposed that correction factors are applied to the calculated burden which takes into consideration the geological variations as shown in Equation 3.9 (see Tables 3.1 and 3.2).

4.2.2 Stemming length

The amount of stemming, measured in metres, is calculated with respect to the practical burden. Under normal conditions, properly designed burden and explosive and good stemming material, a stemming length (T) of 0.7 times the burden (B) is satisfactory to achieve a desired blast fragment and control adverse effect of blasting such as airblast.

$$T = 0.7 \cdot B \quad (4.2)$$

4.2.3 Subdrill

The subdrill (J), also known as sub grade or under grade which represent the extra depth below bench height with the main aim of avoiding bench toes after blasting should be 0.3 times of the actual burden (B). However, in soft seams such as coal formations, subdrilling is avoided so as not to destroy the formation.

$$J = 0.3 \cdot B \quad (4.3)$$

4.2.4 Drillhole length

Depending on the preference of the blasting engineer and the prevailing rock characteristics, a drillhole can either be drilled vertical or inclined. In the case of an inclined drillhole, the vertical projection of the drillhole is considered.

$$L = \frac{H}{\cos \beta} + J \quad (4.4)$$

Where:

L: Drillhole length (m)

H: Bench height/Depth of cut (m)

β: Drillhole angle (degrees)

J: Subdrill (m)

4.2.5 Spacing

According to Assakkaf (2003), spacing is controlled by initiation timing and the stiffness ratio. That is, before the beginning of a spacing analysis, two basic questions are considered:

- Are the charges to be fired instantaneously or delay system will be used?

- Is the stiffness ratio greater than 4?

Normally, a stiffness ratio of value less than 4 is considered a low bench whiles a stiffness ratio of value greater than 4 is considered a high bench.

$$SR = \frac{H}{B} \tag{4.5}$$

Where:

SR: Stiffness ratio

H: Bench height

B: Practical burden

For Delayed Initiation:

$$\text{If } 1 < SR < 4; \qquad S = \frac{H + 7B}{8} \tag{4.6}$$

$$\text{If } SR \geq 4; \qquad S = 1.4 \cdot B \tag{4.7}$$

For Instantaneous Initiation:

$$\text{If } 1 < SR < 4; \qquad S = \frac{H + 2B}{3} \tag{4.8}$$

$$\text{If } SR \geq 4; \qquad S = 2 \cdot B \tag{4.9}$$

Where:

S: Spacing (m)

H: Bench eight (m)

B: Practical burden (m)

4.2.6 Explosive charge length

The explosive charge length is basically the length of drillhole occupied by the explosive material used.

$$L_C = L - T \tag{4.10}$$

Where:

L_C: Explosive charge length (m)

L: Drillhole length (m)

T: Stemming length (m)

4.2.7 Linear charge density

The linear charge density or loading density of an explosive is defined as the weight of the explosive per unit length of the borehole at a specified hole diameter.

$$l_d = \rho_e \cdot \pi \cdot \left(\frac{D_e}{2}\right)^2 \tag{4.11}$$

Where:

l_d: Linear charge density (kg/m)

ρ_e: Density of explosive used (kg/m^3)

D_e: Diameter of explosive used (mm)

4.2.8 Mass of explosive

It is the amount of explosive in a drillhole and can be described as a function of its linear charge density and the length it occupies in a drillhole.

$$Q = l_d \cdot L_C \tag{4.12}$$

Where:

Q: Mass of explosive per hole (kg)

l_d: Linear charge density (kg/m)

L_C: Explosive charge length (m)

4.2.9 Bank Cubic Meters

This is the cubic meter of in-situ material blasted per drillhole in a surface blast.

$$V = \frac{B}{\cos\beta} \cdot S \cdot H \tag{4.13}$$

Where:

V: Cubic bank meters (bcm or m^3)

B: Practical burden (m)

B: Drillhole angle (degrees)

S: Spacing (m)

H: Bench height (m)

4.2.10 Powder factor

Powder factor (q) can be defined as the ratio of the total weight of explosive in the powder column length of a drillhole to the volume of in-situ rock fractured by the explosive weight. It measures the economy of a blast design. In small diameter blasting, the powder factor normally ranges between 0.25 kg/m^3 to 0.55 kg/m^3 whiles in large diameter blasting, the powder factor ranges between 0.25 kg/m^3 to 1.2 kg/m^3 (Jimeno *et al.*, 1995).

$$q = \frac{Q}{V} \tag{4.14}$$

Where:

q: Powder factor (kg/m^3)

Q: Total explosive mass (kg)

V: Total volume of blasted material (bcm/m^3)

4.2.11 Average fragmentation size

This research limits itself to the use of the Kuz-Ram (x_{50}) model which is the most common and widely approach for predicting rock fragmentation size according to Cunningham (1983, 1987).

The x_{50} is a figure that represents the screen size through which 50% of the loosened rock would pass if screened. This implies that a low value represent a fine fragmentation and vice versa. When a complete picture of the fragmentation is required, it is necessary to know the entire distribution. That is, the entire curve and not a single point. Theoretically the same x_{50} values could represent three completely different muck piles. For instance:

- Very fine and very coarse, with nothing in between
- One fraction only, where the size corresponds to x_{50}
- The same amount of all fractions from fines to coarse

The x_{50} which takes into account several parameters can be estimated by the equation created by Kuznetsov and further developed by Cunningham as shown in Equation 3.10.

4.3 COMPUTER ALGORITHM

The software is developed based on the research made on the various blasting theories and it follows the logic as depicted in the flow sheets shown below. It is coded and developed using Microsoft Visual Basic 11 Beta and it is very user friendly. It comprises four windows; the first being the input window where the user inputs the necessary parameters required for the blast design. The second window is also an input window where the user inputs the explosive quantities and its unit cost for the calculation of the cost. The third window shows the output of the blast design. The final window extracts the necessary information from which the user may save as a text file, word file or an excel file.

4.3.1 Flow sheet

The methodology of the software is expressed in a flow sheet to depict the step by step calculation. It explicitly shows the values and factors that must be inputted and selected respectively and the chronological algorithm necessary to obtain the various blast design parameters as shown in Figures 4.1 and 4.2 below.

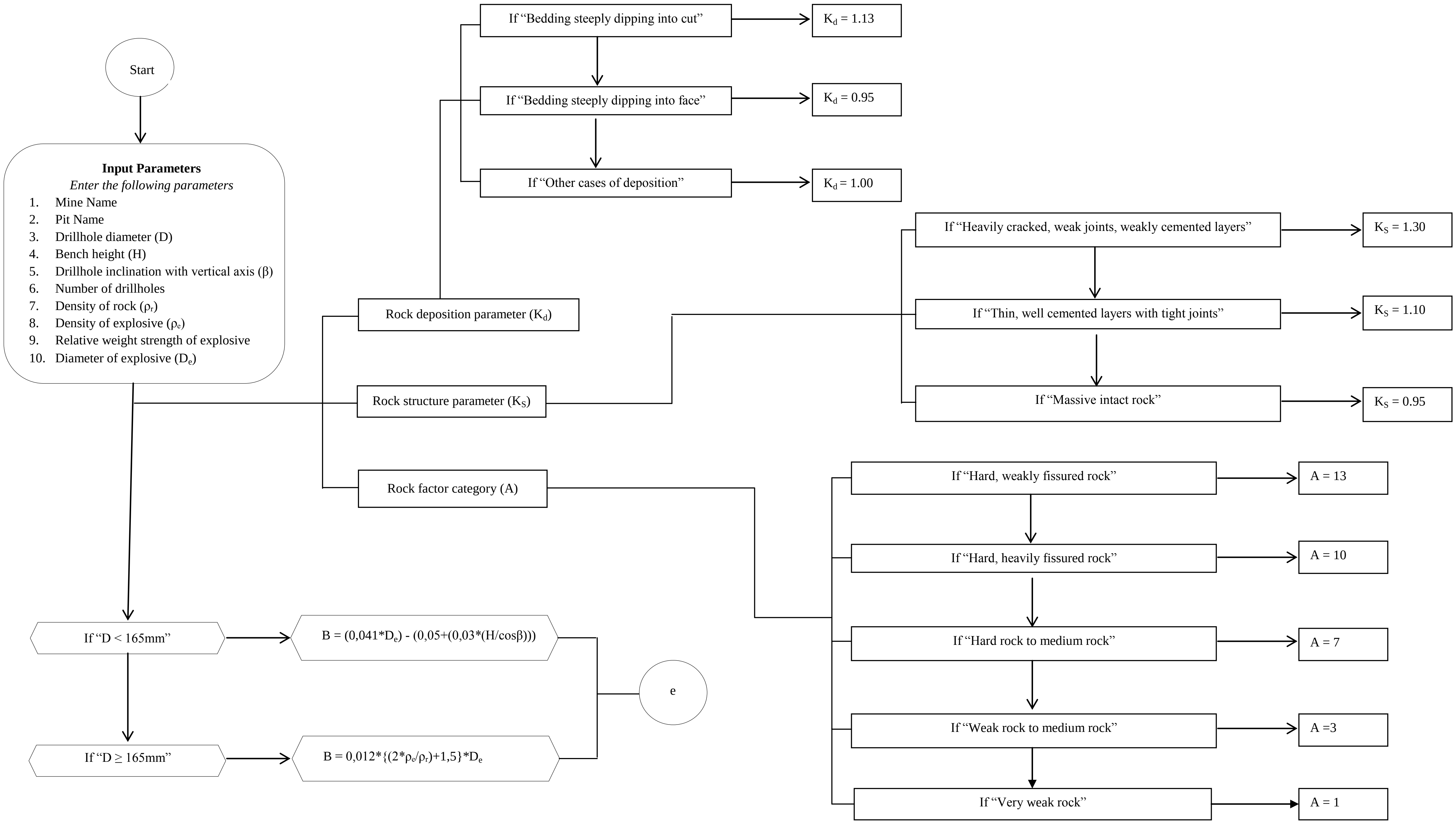


Figure 4.1: Input section

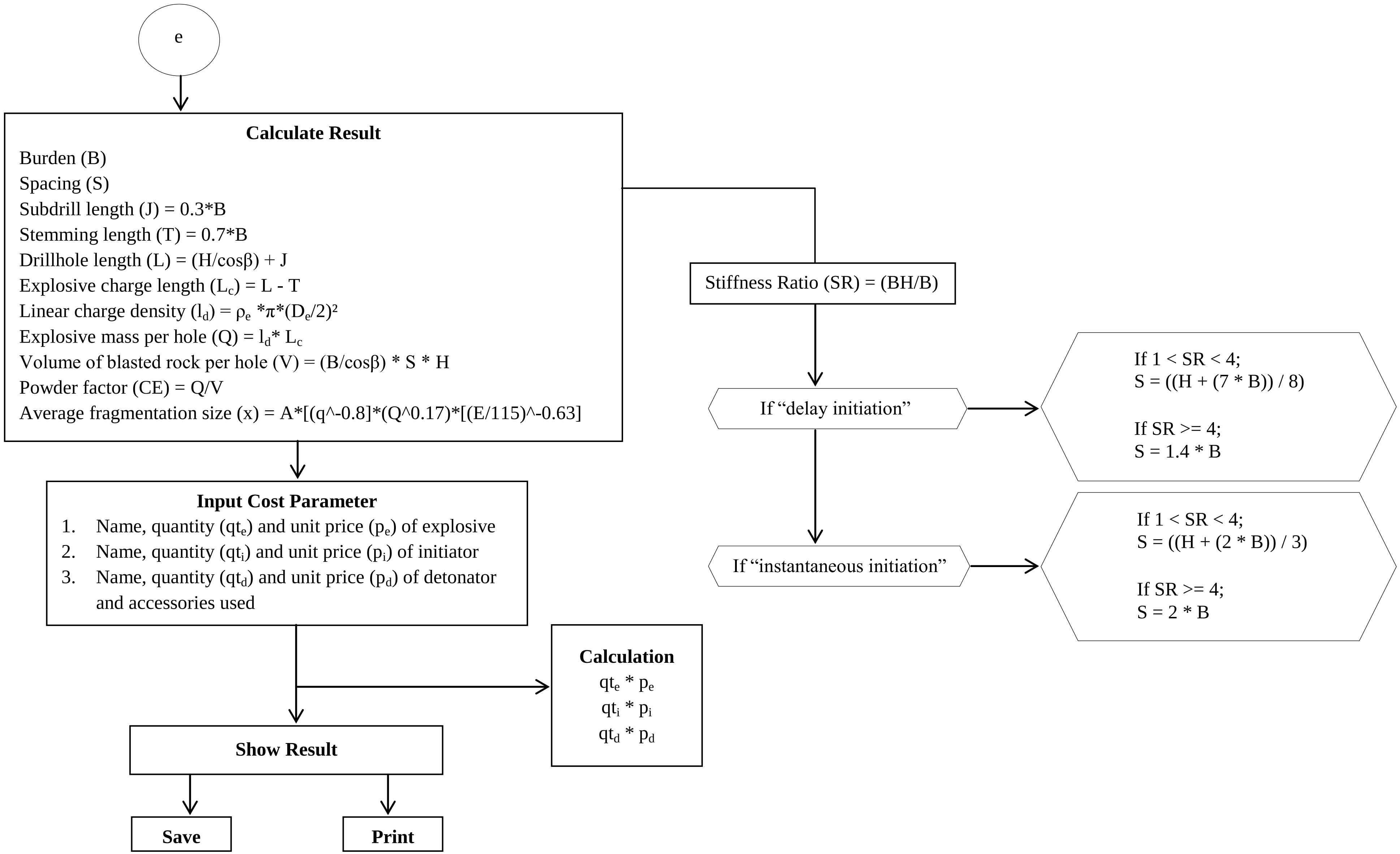


Figure 4.2: Calculation and output section

4.4 THE SOFTWARE

The software (emBLAST v1.0) has been developed and coded using Microsoft Visual Basic 11 Beta and allows installation on any type of Microsoft operating system. It is comprised of a splash screen and four windows.

The splash screen is the start-up page of the software which welcomes the user, giving him a brief idea about the software and manufacturer. The splash screen as been set to 5.0 seconds, after which it disappears, giving way to the next window.

Figure 4.3: Splash screen

The first window is the input window and here, the user inputs the blast parameters necessary for the design of the surface blast. The input parameters have been categorised into the bench parameters which includes the drillhole diameter, bench height, etc.; the rock parameters which includes the rock density, the rock factor, etc.; and the explosive parameters which allows the user to select the type of explosive to be used and its characteristics such as its density and relative weight strength. The next page appears when the user clicks on the 'NEXT' bottom found below the page.

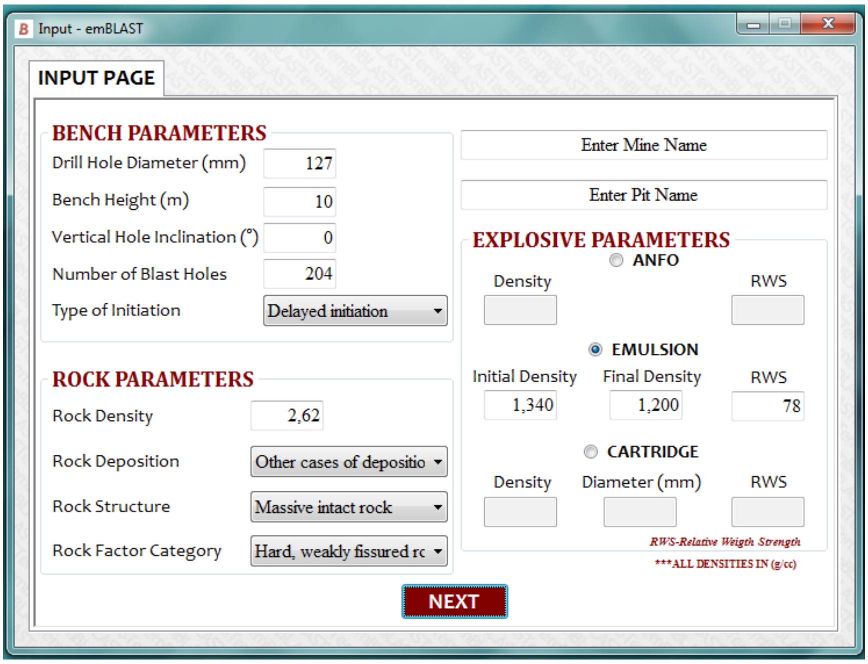


Figure 4.4: Input window

The second window is also an input window. However, the page is designated only for the input of the cost parameters necessary for the blast design. It includes inputting the name, quantity and the unit price of the explosive, booster and the detonators to be used. The next window appears by clicking on the 'DESIGN' bottom found below the page.

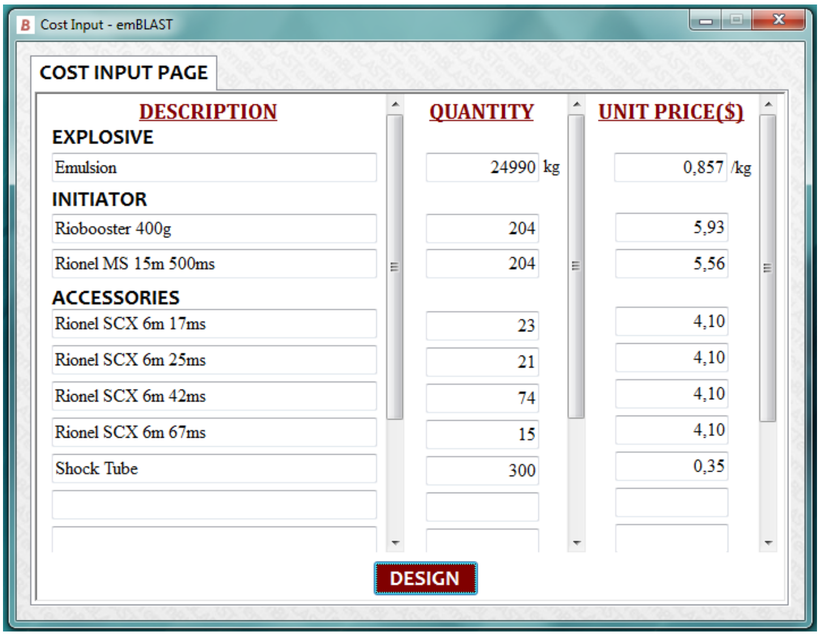


Figure 4.5: Cost input window

The third window is the output window which displays the blast parameters necessary for the design of the surface blast. The parameters includes the burden, spacing, drillhole length, amount of explosive needed, powder factor, blasting cost, estimated fragment size, etc. An 'EXPORT' bottom can be found below the page and its essence is to open the last window.

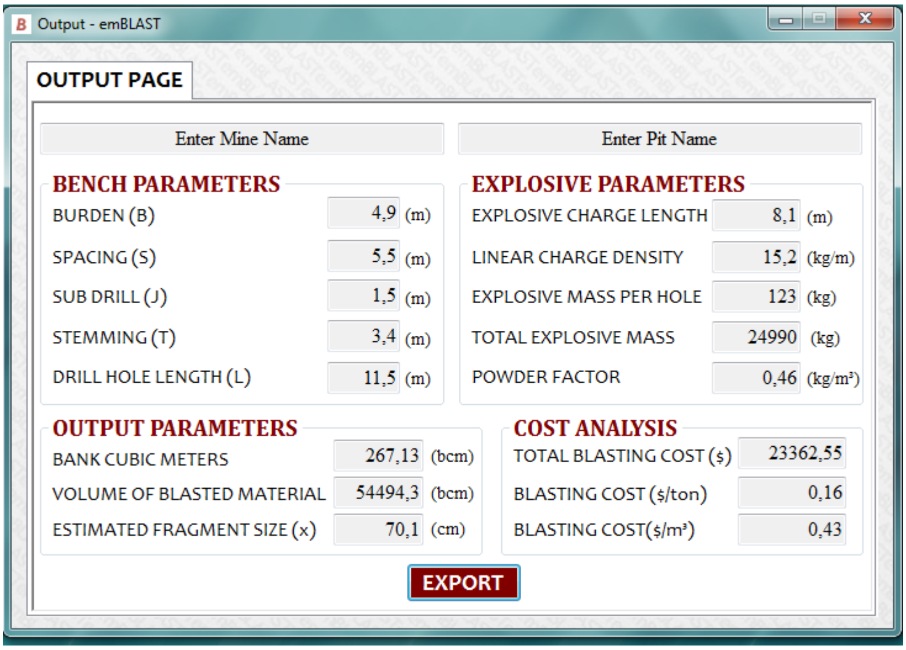


Figure 4.6: Output window

The 'Export' bottom found in the output window exports the result of the blast design to the last window when it is pressed. Here, the designed values can either be printed or saved as a .doc, .xls or .txt extension file for future reference.

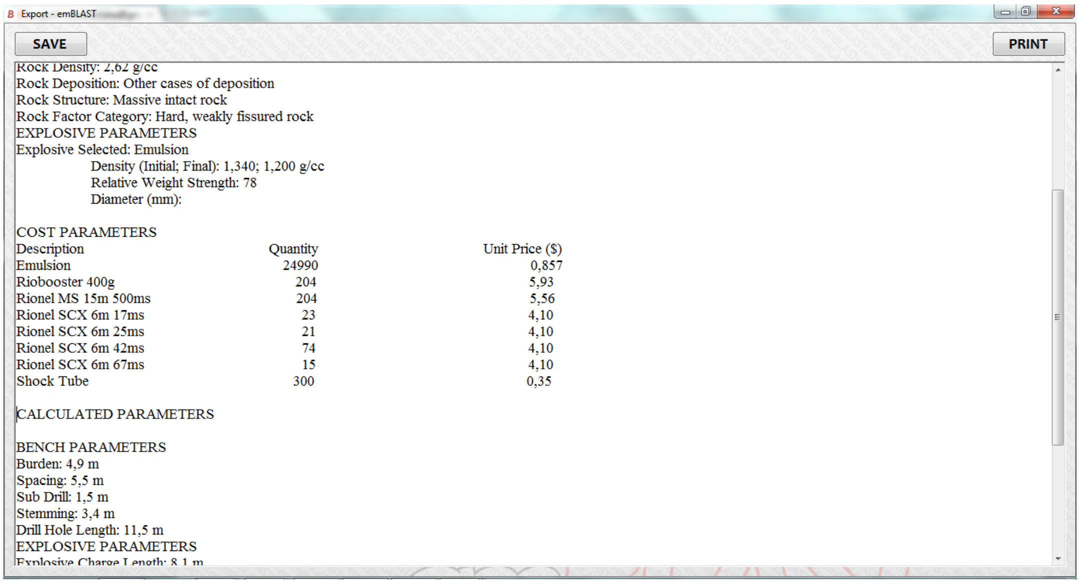


Figure 4.7: Export window

4.5 SOFTWARE VALIDATION AND ANALYSIS OF DATA

The software is validated by using it to perform trial blasts in some mines to evaluate its efficiency.

4.5.1 AngloGold Ashanti, Iduapriem Mine

AngloGold Ashanti, Iduapriem Mine is a gold mine located in Tarkwa, in the western part of Ghana and with an average gold grade of 1.5 g/t. The gold mineralization is located within the Proterozoic Banket Series and it is associated with the Tarkwaian conglomerates found within the matrix that binds the gold pebbles together. The software is tested in the A–Zone pit of the mine with a rock type being auriferous quartzite. The various values and observations are shown in Tables 4.1, 4.2 and 4.3 and Figure 4.8 below.

Table 4.1: Input Parameters

MINE NAME: AngloGold Ashanti, Iduapriem Mine		
PIT NAME: A–Zone Pit		
PARAMETERS		**VALUES**
BENCH	Drillhole Diameter	165 mm
	Bench Height	10 m
	Vertical Hole Inclination	0 °
	Number of Drillholes	215
	Type of Initiation	Delayed initiation
ROCK	Rock Density	2.65 g/cm^3
	Rock Deposition	Other cases of deposition
	Rock Structure	Thin, well-cemented layers with tight joints
	Rock Factor Category	Hard rock to medium rock
EXPLOSIVE	Explosive type: Emulsion (emunex 8000)	Initial Density: 1.308 g/cm^3
		Final Density: 1.147 g/cm^3
		RWS: 78

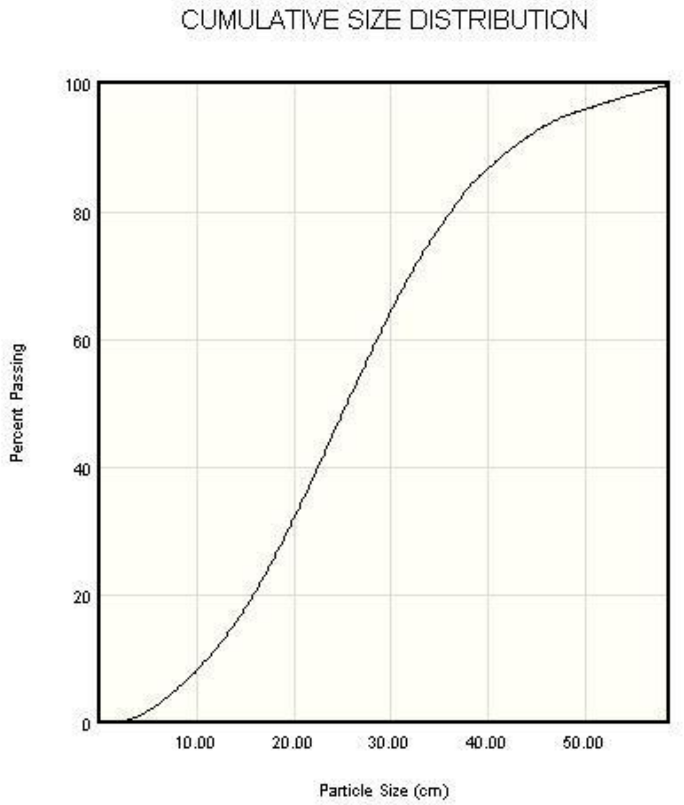
The initial density of the explosive is the cap density of that explosive measured immediately after charging a drillhole while the final density of the explosive is the cap density measured 45 minutes after the measure of its initial density.

Table 4.2: Calculated Parameters

MINE NAME: Iduapriem Gold Mine		
PIT NAME: A–Zone Pit		
PARAMETERS		**VALUES**
BENCH	Burden (B)	5.2 m
	Spacing (S)	5.8 m
	Subdrill (J)	1.5 m
	Stemming Length (T)	3.6 m
	Drillhole Length (L)	11.5 m
EXPLOSIVE	Explosive Charge Length	7.9 m
	Linear Charge Density	24.53 kg/m
	Explosive Mass per Hole	195 kg
	Total Explosive Mass	41,863 kg
	Powder Factor	0.66 kg/m^3
OUTPUT	Bank Cubic Meters	296.69 bcm
	Volume of Blasted Material	63,789.23 bcm
	Estimated Fragment Size (x_{50})	30.7 cm
COST	Total Blasting Cost	$44,521,34
	Blasting Cost per Ton	$0.34/ton
	Blasting Cost per Volume of loose material	$0.94/m^3

Table 4.3: Observations

OBSERVED PARAMETERS	**VALUES/OBSERVATIONS**
Average Fragmentation Size (x_{50})	25.5 cm *(as shown in Figure 4.8 below)*
Ground Vibration	3.4 mm/s
Air Vibration	113 dB
Flyrocks	Flyrock projections within the blast area (≤ 50 m circumference from blast are) without causing damage to man or machines.



size (mm)	%
1905.00	100.00
1270.00	100.00
635.00	100.00
381.00	83.95
254.00	49.69
203.20	32.95
152.40	18.53
101.60	8.53
50.80	1.97
38.10	0.96
25.40	0.33
19.05	0.15
12.70	0.05
9.525	0.02
6.350	0.00
4.750	0.00
1.999	0.00

P20 Size (mm) 158.40
P50 Size (mm) 254.94
P80 Size (mm) 361.84
Top size (mm) 578.09

Figure 4.8: Fragment size distribution curve for A-Zone blast

The blast was designed according to the parameters in Tables 4.1 and 4.2. The resulting x_{50} measured with Split showed a difference of 5.2 cm (20 % decrees) with respect to the estimated (calculated) fragment size. The ground vibration recorded was 0.4 mm/s (12 %) higher than the limit of >3.0 mm/s set by the mine. However, it fell within the limit set by the blasting regulation of the host country (>5 mm/s). It also recorded an air vibration falling within the set limit of 120 dB (113 dB) and observed that there were few flyrocks which did not go beyond 50 m as stipulated by the mine.

4.5.2 Adamus Resources

Adamus Resources is a gold mine located in Tarkwa, in the western part of Ghana. It is located at the southern end of the Ashanti gold belt with its principal mineralization being sulphide gold and having an average grade of 1.3 g/t. The software is tested in the S South pit of the mine with the rock type being laterite oxide. The various values and observations are shown in Tables 4.4, 4.5 and 4.6 and Figure 4.9 below.

Table 4.4: Input Parameters

MINE NAME: Adamus Resources		
PIT NAME: S South Pit		
PARAMETERS		**VALUES**
BENCH	Drillhole Diameter	115 mm
	Bench Height	6 m
	Vertical Hole Inclination	0 °
	Number of Drillholes	179
	Type of Initiation	Delayed initiation
ROCK	Rock Density	1.87 g/cc
	Rock Deposition	Other cases of deposition
	Rock Structure	Heavily cracked, weak joints, weakly cemented layer
	Rock Factor Category	Medium to weak rock
EXPLOSIVE	Explosive type: Emulsion (emunex 8000)	Initial Density: 1.317 g/cc
		Final Density: 1.05 g/cc
		RWS: 78

The initial density of the explosive is the cap density of that explosive measured immediately after charging a drillhole while the final density of the explosive is the cap density measured 45 minutes after the measure of its initial density.

Table 4.5: Calculated Parameters

MINE NAME: Adamus Resources		
PIT NAME: S South Pit		
PARAMETERS		**VALUES**
BENCH	Burden (B)	4.5 m
	Spacing (S)	4.7 m
	Subdrill (J)	1.3 m
	Stemming Length (T)	3.1 m
	Drillhole Length (L)	7.3 m
EXPLOSIVE	Explosive Charge Length	4.2 m
	Linear Charge Density	10.91 kg/m
	Explosive Mass per Hole	46 kg
	Total Explosive Mass	8,213 kg
	Powder Factor	0.36 kg/m^3
OUTPUT	Bank Cubic Meters	125.79 bcm
	Volume of Blasted Material	22,515.95 bcm
	Estimated Fragment Size (x)	21,9 cm
COST	Total Blasting Cost	$10,581.98
	Blasting Cost per Ton	$0.27/ton
	Blasting Cost per Volume of loose material	$0.5/$m^3$

Table 4.6: Observations

OBSERVED PARAMETERS	**VALUES/OBSERVATIONS**
Average Fragmentation Size (x_{50})	23.1 cm *(as shown in Figure 4.9 below)*
Ground Vibration	3.2 mm/s
Air Vibration	116 dB
Flyrocks	Flyrock projections within the blast area (≤ 50 m circumference from blast are) without causing damage to man or machines.

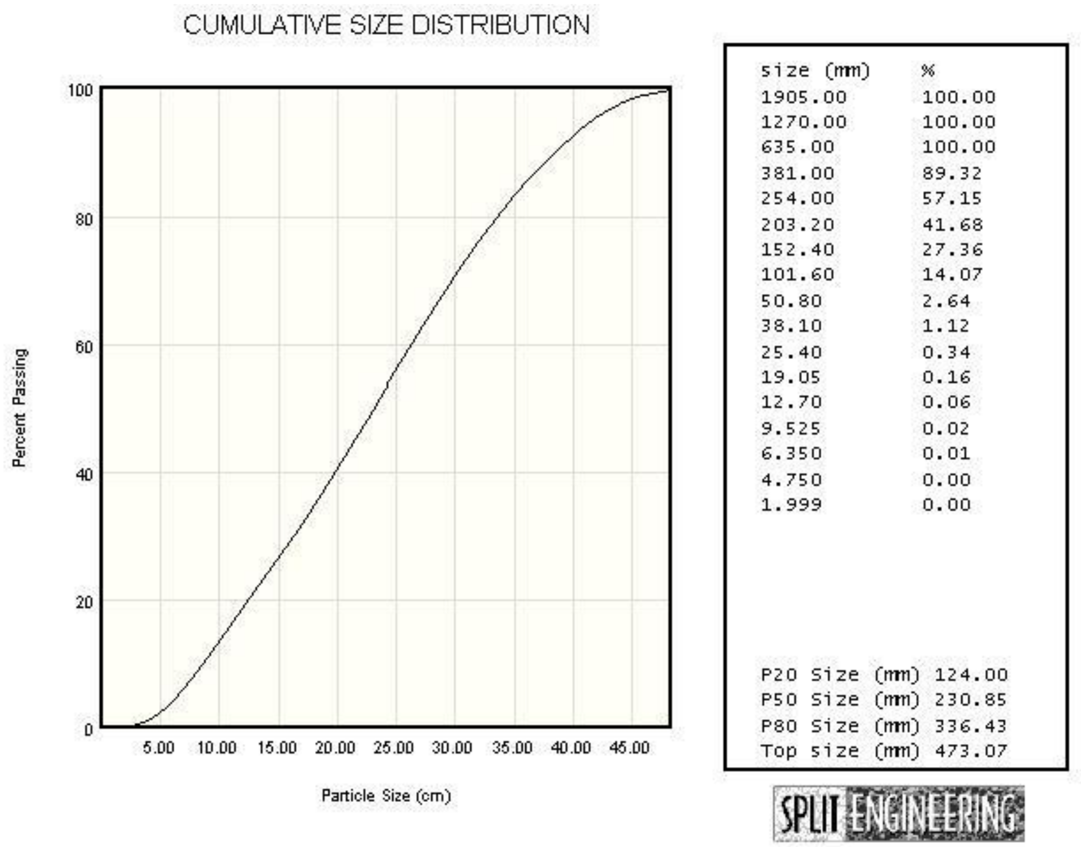


Figure 4.9: Fragment size distribution curve for S South blast

The blast was designed according to the parameters in Tables 4.4 and 4.5. The resulting x_{50} measured with Split showed a difference of 1.1 cm (4.6 % increase) with respect to the estimated (calculated) fragment size. The ground vibration recorded was 0.2 mm/s (6.7 %) higher than the limit of >3.0 mm/s set by the mine. However, it fell within the limit set by the blasting regulation of the host country (>5 mm/s). It also recorded an air vibration falling within the set limit of 120 dB (116 dB) and observed that there were few flyrocks which did not go beyond 50 m as stipulated by the mine.

4.5.3 Bonikro Gold Mine

Bonikro Gold Mine is a gold mining company with an 85% shares owned by Newcrest Mining Company. The mine is located in Hiré in the central-southern part of Côte d'Ivoire. The deposit is hosted primarily within a small granadiroite intrusion and the gold is associated with quartz and pyrite with an average grade below 2 g/t gold. The software is tested in Bonikro pit of the mine with the observed rock type being granite. The various values and observations are shown in Tables 4.7, 4.8 and 4.9 and Figure 4.10 below.

Table 4.7: Input Parameters

<table>
<tr><td colspan="3">MINE NAME: Bonikro Gold Mine</td></tr>
<tr><td colspan="3">PIT NAME: Bonikro Pit</td></tr>
<tr><th colspan="2">PARAMETERS</th><th>VALUES</th></tr>
<tr><td rowspan="5">BENCH</td><td>Drillhole Diameter</td><td>127 mm</td></tr>
<tr><td>Bench Height</td><td>10 m</td></tr>
<tr><td>Vertical Hole Inclination</td><td>0 °</td></tr>
<tr><td>Number of Drillholes</td><td>204</td></tr>
<tr><td>Type of Initiation</td><td>Delayed initiation</td></tr>
<tr><td rowspan="4">ROCK</td><td>Rock Density</td><td>2.62 g/cc</td></tr>
<tr><td>Rock Deposition</td><td>Other cases of deposition</td></tr>
<tr><td>Rock Structure</td><td>Thin, well-cemented layers with tight joints</td></tr>
<tr><td>Rock Factor Category</td><td>Hard to medium rock</td></tr>
<tr><td rowspan="3">EXPLOSIVE</td><td rowspan="3">Explosive type: Emulsion (emunex 8000)</td><td>Initial Density: 1.34 g/cc</td></tr>
<tr><td>Final Density: 1.20 g/cc</td></tr>
<tr><td>RWS: 78</td></tr>
</table>

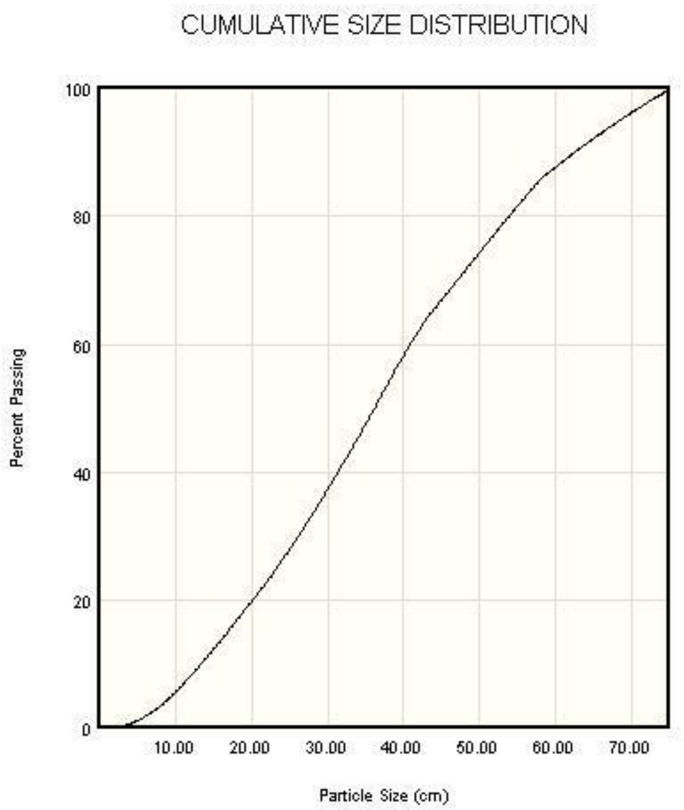
The initial density of the explosive is the cap density of that explosive measured immediately after charging a drillhole while the final density of the explosive is the cap density measured 45 minutes after the measure of its initial density.

Table 4.8: Calculated Parameters

MINE NAME: Bonikro Gold Mine		
PIT NAME: Bonikro Pit		
PARAMETERS		**VALUES**
BENCH	Burden (B)	4.9 m
	Spacing (S)	5.5 m
	Subdrill (J)	1.5 m
	Stemming Length (T)	3.4 m
	Drillhole Length (L)	11.5 m
EXPLOSIVE	Explosive Charge Length	8.1 m
	Linear Charge Density	15.2 kg/m
	Explosive Mass per Hole	122 kg
	Total Explosive Mass	24,986 kg
	Powder Factor	0.46 kg/m^3
OUTPUT	Bank Cubic Meters	267.13 bcm
	Volume of Blasted Material	54,494.3 bcm
	Estimated Fragment Size (x)	37.8 cm
COST	Total Blasting Cost	$23,329.92
	Blasting Cost per Ton	$0.17/ton
	Blasting Cost per Volume of loose material	$0.43/$m^3$

Table 4.9: Observations

OBSERVED PARAMETERS	**VALUES/OBSERVATIONS**
Average Fragmentation Size (x_{50})	36.2 cm *(as shown in Figure 4.10 below)*
Ground Vibration	4.6 mm/s
Air Vibration	115 dB
Flyrocks	Flyrock projections within the blast area (≤ 50 m circumference from blast are) without causing damage to man or machines.



size (mm)	%
1905.00	100.00
1270.00	100.00
635.00	90.85
381.00	54.19
254.00	28.67
203.20	20.30
152.40	12.69
101.60	5.86
50.80	1.22
38.10	0.58
25.40	0.18
19.05	0.08
12.70	0.03
9.525	0.01
6.350	0.00
4.750	0.00
1.999	0.00

P20 Size (mm) 201.21
P50 Size (mm) 361.79
P80 Size (mm) 538.82
Top size (mm) 745.59

Figure 4.10: Fragment size distribution curve for Bonikro blast

The blast was designed according to the parameters in Tables 4.7 and 4.8. The resulting x_{50} measured with Split showed a difference of 1.6 cm (4.4 % decrees) with respect to the estimated (calculated) fragment size. The ground vibration however fell within the limit set by the blasting regulation of the host country which was apparently equal to the >10 mm/s limit set by the mine. It also recorded an air vibration falling within the set limit of 120 dB (115 dB) and observed that there were few flyrocks which did not go beyond 50 m as stipulated by the mine.

5 CONCLUSIONS

The two main blasting variables have been researched extensively and based on these, a review of the various parameters affecting surface blast and its output parameters have been studied, with the key parameters emphatically analysed. Over the years, blast theories have been proposed, utilizing the various blasting parameters by several researchers such as Konya and Walter, Ash, Langefors and Kilhstrom, etc. with the aim of maximizing explosive output at a relatively minimum blasting cost such that the blasting output conforms to the blast regulations of the host country. Some of these theories have been very efficient in the design of a surface blast and as such, are used by several blast engineers all over the world. However, the method of calculating the various blast design parameters manually is cumbersome and time-consuming and therefore, there was the need to build a simple and user-friendly computer software for the design of the surface blast.

This was achieved by firstly studying extensively on the various controllable and uncontrollable blasting parameters. The blast theories proposed by various blast researchers were also studied which much emphasis on the most efficient and widely used theories; the Swedish Blasting Theory for small diameter blasting, the Konya and Walter formula for large diameter blasting and the Kuz-Ram Model for the calculation of the average fragment size. Based on these studies, a software was developed and coded using Microsoft Visual Basic 11 Beta for the purpose of designing a surface blast and analysing the cost of blasting. This software helps in reducing working time, performing several iterations and saving blasting results for the purpose of posterity.

The software was then validated by using it to perform pilot blast in specimen mines having different field and working condition. The main emphasis of the pilot blast was on the blast output parameters, specifically on the average fragmentation size, the ground vibration, the air vibration and the nature of flyrocks. The results showed an almost equal value in the amount of explosive used and the total volume of blasted material produced. There was also a significant difference within the range of ±5 cm between the computed average fragment size and the field´s average fragment size. The ground vibration generally showed a high peak particle velocity compared to the limit set by the various mine although it fell within the acceptable range set by the blasting regulation in the host countries. However, the airblast level and the flyrock fell within the limits which have been set by both the host mines and the blasting regulations within the host country.

The software is currently in a demo version and as such has limited use. However, the researcher hopes to improve upon it by adding a lot of features to be able to perform comprehensive functions such as firing pattern designing and drillhole pattern designing so as to meet modern blasting techniques.

Finally, looking at the results obtained from the pilot blast and in comparison with the general blasting regulations set by the both the host mine and the host country, it can be concluded generally that the blast parameters calculated by the software where very close to the actual results obtained on the field although it showed few and acceptable variations in some results as it does not run a significant amount of causing risk or collateral damage if rules and regulations concerning mine blasting are observed by all and sundry.

6 REFERENCES

Allsman, P.L. (1960): Analysis of Explosives Action in Breaking Rocks, Transactions of AIME, pp. 217, 468-478

Anon. (2010): "*Goldfields-Tarkwa Gold Mine*", www.gold-fields.com, Accessed on 15th May, 2012.

Anon (2012a): http://en.wikipedia.org/wiki/Lithology, Accessed on 24th May, 2012

Anon (2012b): http://en.wikipedia.org/wiki/Mineral#Mineral_composition_of_rocks Accessed on 24th May, 2012.

Anon (2012c): http://en.wikipedia.org/wiki/Rock_type, Accessed on 24th May, 2012.

Anon (2012d): http://www.techtransfer.osmre.gov/nttmainsite/library/hbmanual/btm/module_3.pdf, Accessed on 24th May, 2012.

Ash, R. L. (1968): Surface Mining, American Institute of Mining and Petroleum Engineers, New York, USA, pp. 343-397.

Assakkaf I. (2003): Construction Planning, Equipment and Methods (6th Ed.), McGraw-Hill, New York.

Bell, F. G. (1983): Fundamentals of Engineering Geology, Butterworth's, London, 684pp

Budavari, S. (1983): Rock Mechanics in Mining Practices. Monograph Series No. 5. The South African Institute of Mining and Metallurgy, Johannesburg.

Cunningham, C. (1983): "*The Kuz-Ram Model for Prediction of Fragmentation from Blasting*"; Proceedings on First International Symposium on Rock Fragmentation by Blasting, August 23-26, 1983. Lulea, Sweden.

Cunningham, C. (1987): "*Fragmentation Estimations and the Kuz-Ram Model – Four Years On*"; Proceedings on, Second International Symposium on Rock Fragmentation by Blasting, August 23-26, 1987. Colorado. pp. 450, 480, 481.

Djordjevic, N., (1999): "*Two-component Blast Fragmentation*", Proceedings of the 6th International Symposium on Rock Fragmentation by Blasting-Flag blast, South Africa Institute of Mining and Metallurgy, Johannesburg. South Africa, pp. 213-219.

Gustafson, R. (1973): Swedish Blasting Technique, SPI, Gothenburg, Sweden. pp. 58-63.

Hemphill G.B. (1981): Blasting Operations. McGraw-Hill, New York.

Hustrulid, W. (1999): "Blasting Principles for Open Pit Mining". Vol. I. A.A. Balkema, Rotterdam. pp. 27- 31, 38-39, 42-44, 73 & 77, 854-855.

Jimeno, L.C. *et al* (1995): Drilling and Blasting of Rocks. A.A Belkema, Rotterdam. pp. 179-189

Konya, C. J. and Walter, E. J. (1990): Surface Blast Design. Prentice-Hall Inc. pp. 114 – 146

Kuznestsov, V.M. (1973): Soviet Mining Science Vol. 9, no. 2, pp. 144-148

Langefors, U. and Kihlstrom, B. (1978): *"Short Delay Blasting Multiple – Row Rounds"*, The Modern Technique of Rock Blasting, 3rd Edition, Alasted Press Book, New York, pp. 139 - 178.

Lilly, P.A. (1986): *"An Empirical Method of Assessing Rock Mass Blastability*." Proceedings, Large Open Pit Mining Conference (J.R. Davidson, ed.), The AUSIMM, Parkville, Victoria. pp. 89-92.

Morhard R.C (1987): Explosives and Rock Blasting. Atlas Powder Company, Dallas, Texas pp. 295 – 304

Oloffson, S. O. (1988): Applied Explosives Technology for Construction and Mining, Applex Publishers, Arla, Sweden, pp. 13-241.

Partha D.S. (2010): http://miningandblasting.wordpress.com, Accessed on 29th May, 2012.

Speath, G.L. (1960): Formula for Proper Blasthole Spacing, Engineering News Record 218(3):53

Tandanand, S. (1973): "*Principles of Drilling*". SME, Mining Engineering Hand Book, Vol. I, Section 11, (Cummins A.B. and Given, I.A. ed.) pp. 5-8, 12-13.

Temeng, V.A. (2010): *"Surface Mining Systems"*, Unpublished BSc Lecture Notes, University of Mines and Technology, Tarkwa, p. 12.

Yomekpe-Agbeno, S. K. (2008): "*Ground Fragmentation*", Unpublished BSc Lecture Notes, University of Mines and Technology (UMaT), Tarkwa, 100pp.

UN SOFTWARE PARA EL DISEÑO DE VOLADURAS EN MINERÍA A CIELO ABIERTO

DOCUMENT N^{O} 2: ECONOMIC STUDIES

1 BUDGET

DIRECT COST

Designing, coding and producing of the software .... 500.00€

Hiring of equipment's for pilot blasting for 4 days .... 10,000.00€

Subtotal A.. 10,500.00€

Overhead Cost (10%)... 1,050.00€

Total B = (A + Overhead Cost)... 11,550.00€

IVA (18%)... 2,079.00€

GRAND TOTAL = (B + IVA)... 13,629.00€

UN SOFTWARE PARA EL DISEÑO DE VOLADURAS EN MINERÍA A CIELO ABIERTO

DOCUMENT N^{O} 3: ANNEXES

ANNEX A: PROGRAMMING emBLAST

```
Public Class Splash_Screen

    Private Sub Splash_Screen_Load(sender As Object, e As EventArgs) Handles MyBase.Load
        Timer1.Start()
    End Sub

    Private Sub Timer1_Tick(sender As Object, e As EventArgs) Handles Timer1.Tick
        ProgressBar1.Increment(20)
        If ProgressBar1.Value = 200 Then
            Me.Close()
            frmInput.Show()
        End If
    End Sub

End Class
```

```
Public Class frmInput
    Dim DrillHDiam, BHeight, DegOInc, NoBHoles As Double
    Dim DelayedIni, InstantIni As Double
    Dim ANFODen, ANFORWS As Double
    Dim IniEmulsDen, FinEmulsDen, EmulsRWS As Double
    Dim CatrDen, CatrDia, CatrRWS As Double
    Dim RockDens As Double
    Dim HardWfissured, HardHfissured, MediumHRock, WeakMRock, VeryWRock As Double
    Dim BeddingICut, BeddingIFace, OtherDep As Double
    Dim HeavilyCracked, ThinWCemented, MassiveIntRock As Double
    Dim B1, B, T, J, L, SR, S, Y, Q1, Q2, Q3, V, Vt, CE, x, Ks, Kd, A As Double

    Private Sub frmemBLAST_Load(sender As Object, e As EventArgs) Handles MyBase.Load
        cmboTypeInitiation.SelectedIndex = 0
        cmboRockDeposition.SelectedIndex = 0
        cmboRockStructure.SelectedIndex = 0
        cmboGRockCategory.SelectedIndex = 0

        If rbtnANFO.Checked = False Then
            txtDensityANFO.Enabled = False
            txtRWSANFO.Enabled = False
        End If
        If rbtnEmulsion.Checked = False Then
            txtInitialDensityEmul.Enabled = False
            txtFinalDensityEmul.Enabled = False
            txtRWSEmul.Enabled = False
        End If
        If rbtnCartridge.Checked = False Then
            txtDensityCartridge.Enabled = False
            txtDiameterCartridge.Enabled = False
            txtRWSCartridge.Enabled = False
        End If
    End Sub

    Public Sub TypeInitiation()
        If cmboTypeInitiation.SelectedIndex = 0 Then
            A = 0
            MsgBox("Please select type of initiation", MsgBoxStyle.Information, "Select Initiation Type")
```

```
        End If
        If cmboTypeInitiation.SelectedIndex = 1 Then
            If 1 < SR < 4 Then
                S = ((BHeight + (7 * B)) / 8)
            End If
            If SR >= 4 Then
                S = 1.4 * B
            End If
        ElseIf cmboTypeInitiation.SelectedIndex = 2 Then
            If 1 < SR < 4 Then
                S = ((BHeight + (2 * B)) / 3)
            End If
            If SR >= 4 Then
                S = 2 * B
            End If
        End If
    End Sub

    Public Sub RockDeposition()
        If cmboRockDeposition.SelectedIndex = 0 Then
            Kd = 0
            MsgBox("Please select rock deposition parameter", MsgBoxStyle.Information, "Select Rock
Deposition Parameter")
        End If
        If cmboRockDeposition.SelectedIndex = 1 Then
            BeddingICut = Kd
            Kd = 1.13
        ElseIf cmboRockDeposition.SelectedIndex = 2 Then
            BeddingIFace = Kd
            Kd = 0.95
        ElseIf cmboRockDeposition.SelectedIndex = 3 Then
            OtherDep = Kd
            Kd = 1.0
        End If
    End Sub

    Public Sub RockStructure()
        If cmboRockStructure.SelectedIndex = 0 Then
            Ks = 0
            MsgBox("Please select rock structure parameter", MsgBoxStyle.Information, "Select Rock
Structure Parameter")
        End If
        If cmboRockStructure.SelectedIndex = 1 Then
            HeavilyCracked = Ks
            Ks = 1.3
        ElseIf cmboRockStructure.SelectedIndex = 2 Then
            ThinWCemented = Ks
            Ks = 1.1
        ElseIf cmboRockStructure.SelectedIndex = 3 Then
            MassiveIntRock = Ks
            Ks = 0.95
        End If
    End Sub

    Public Sub GRockCategory()
        If cmboGRockCategory.SelectedIndex = 0 Then
            A = 0
            MsgBox("Please select general rock category", MsgBoxStyle.Information, "Select Rock
Category")
        End If
```

```
        If cmboGRockCategory.SelectedIndex = 1 Then
            HardWfissured = A
            A = 13
        ElseIf cmboGRockCategory.SelectedIndex = 2 Then
            HardHfissured = A
            A = 10
        ElseIf cmboGRockCategory.SelectedIndex = 3 Then
            MediumHRock = A
            A = 7
        ElseIf cmboGRockCategory.SelectedIndex = 4 Then
            WeakMRock = A
            A = 4
        ElseIf cmboGRockCategory.SelectedIndex = 5 Then
            VeryWRock = A
            A = 1
        End If
    End Sub

    Private Sub txtMineName_Enter(sender As Object, e As EventArgs) Handles txtMineName.Enter
        If txtMineName.Text() = "Enter Mine Name" Then
            txtMineName.Text = ""
        End If
    End Sub

    Private Sub txtPitName_Enter(sender As Object, e As EventArgs) Handles txtPitName.Enter
        If txtPitName.Text() = "Enter Pit Name" Then
            txtPitName.Text = ""
        End If
    End Sub

    Private Sub txtMineName_Validated(sender As Object, e As EventArgs) Handles
txtMineName.Validated
        If txtMineName.Text = "" Then
            txtMineName.Text = "Enter Mine Name"
        Else
        End If
    End Sub

    Private Sub txtPitName_Validated(sender As Object, e As EventArgs) Handles txtPitName.Validated
        If txtPitName.Text = "" Then
            txtPitName.Text = "Enter Pit Name"
        Else
        End If
    End Sub

    Private Sub txtDrillHDiamter_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtDrillHDiamter.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub
```

```
    Private Sub txtDrillHDiamter_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtDrillHDiamter.Validating
        If txtDrillHDiamter.Text = "" Then
            txtDrillHDiamter.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtBenchHeight_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtBenchHeight.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtBenchHeight_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtBenchHeight.Validating
        If txtBenchHeight.Text = "" Then
            txtBenchHeight.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtBlastHInclination_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtBlastHInclination.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtBlastHInclination_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtBlastHInclination.Validating
        If txtBlastHInclination.Text = "" Then
            txtBlastHInclination.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        ElseIf txtBlastHInclination.Text > 30 Then
            txtBlastHInclination.Focus()
            MsgBox("Angle of inclination(β) = 0 for vertical hole; and 0<β<30", MsgBoxStyle.Information,
"Error in Inclination Angle")
        End If
    End Sub

    Private Sub txtNoBlastHoles_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtNoBlastHoles.KeyPress
        Dim ch As Char = e.KeyChar
```

```
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtNoBlastHoles_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtNoBlastHoles.Validating
        If txtNoBlastHoles.Text = "" Then
            txtNoBlastHoles.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtRockDensity_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtRockDensity.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtRockDensity_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtRockDensity.Validating
        If txtRockDensity.Text = "" Then
            txtRockDensity.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtDensityANFO_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtDensityANFO.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtDensityANFO_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtDensityANFO.Validating
        If txtDensityANFO.Text = "" Then
            txtDensityANFO.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Requierd Value")
```

```
        End If
    End Sub

    Private Sub txtRWSANFO_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtRWSANFO.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtRWSANFO_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtRWSANFO.Validating
        If txtRWSANFO.Text = "" Then
            txtRWSANFO.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtInitialDensityEmul_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtInitialDensityEmul.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtInitialDensityEmul_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtInitialDensityEmul.Validating
        If txtInitialDensityEmul.Text = "" Then
            txtInitialDensityEmul.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtFinalDensityEmul_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtFinalDensityEmul.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub
```

```
    Private Sub txtFinalDensityEmul_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtFinalDensityEmul.Validating
        If txtFinalDensityEmul.Text = "" Then
            txtFinalDensityEmul.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtRWSEmul_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtRWSEmul.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtRWSEmul_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtRWSEmul.Validating
        If txtRWSEmul.Text = "" Then
            txtRWSEmul.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtDensityCartridge_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtDensityCartridge.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtDensityCartridge_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtDensityCartridge.Validating
        If txtDensityCartridge.Text = "" Then
            txtDensityCartridge.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtDiameterCartridge_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtDiameterCartridge.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
```

```
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtDiameterCartridge_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtDiameterCartridge.Validating
        If txtDiameterCartridge.Text = "" Then
            txtDiameterCartridge.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub

    Private Sub txtRWSCartridge_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtRWSCartridge.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtRWSCartridge_Validating(sender As Object, e As
System.ComponentModel.CancelEventArgs) Handles txtRWSCartridge.Validating
        If txtRWSCartridge.Text = "" Then
            txtRWSCartridge.Focus()
            MsgBox("Please enter the required value", MsgBoxStyle.Information, "Enter Required Value")
        End If
    End Sub


    Private Sub rbtnANFO_CheckedChanged(sender As Object, e As EventArgs) Handles
rbtnANFO.CheckedChanged
        If rbtnANFO.Checked = True Then
            frmCostInput.txtDESEXPLOSIVE.Text = "ANFO"
            txtDensityANFO.Enabled = True
            txtRWSANFO.Enabled = True
        Else
            txtDensityANFO.Enabled = False
            txtDensityANFO.Text = ""
            txtRWSANFO.Enabled = False
            txtRWSANFO.Text = ""
        End If
    End Sub

    Private Sub rbtnEmulsion_CheckedChanged(sender As Object, e As EventArgs) Handles
rbtnEmulsion.CheckedChanged
        If rbtnEmulsion.Checked = True Then
            frmCostInput.txtDESEXPLOSIVE.Text = "Emulsion"
            txtInitialDensityEmul.Enabled = True
            txtFinalDensityEmul.Enabled = True
            txtRWSEmul.Enabled = True
```

```
        Else
            txtInitialDensityEmul.Enabled = False
            txtInitialDensityEmul.Text = ""
            txtFinalDensityEmul.Enabled = False
            txtFinalDensityEmul.Text = ""
            txtRWSEmul.Enabled = False
            txtRWSEmul.Text = ""
        End If
    End Sub

    Private Sub rbtnCartridge_CheckedChanged(sender As Object, e As EventArgs) Handles
rbtnCartridge.CheckedChanged
        If rbtnCartridge.Checked = True Then
            frmCostInput.txtDESEXPLOSIVE.Text = "Cartridge"
            txtDensityCartridge.Enabled = True
            txtDiameterCartridge.Enabled = True
            txtRWSCartridge.Enabled = True
        Else
            txtDensityCartridge.Enabled = False
            txtDensityCartridge.Text = ""
            txtDiameterCartridge.Enabled = False
            txtDiameterCartridge.Text = ""
            txtRWSCartridge.Enabled = False
            txtRWSCartridge.Text = ""
        End If
    End Sub

    Public Sub btnDesign_Click(sender As Object, e As EventArgs) Handles btnNext.Click
        If txtDrillHDiamter.Text <> "" Then
            DrillHDiam = txtDrillHDiamter.Text
        End If
        If txtBenchHeight.Text <> "" Then
            BHeight = txtBenchHeight.Text
        End If
        If txtBlastHInclination.Text <> "" Then
            DegOInc = txtBlastHInclination.Text
        End If
        If txtNoBlastHoles.Text <> "" Then
            NoBHoles = txtNoBlastHoles.Text
        End If
        If txtRockDensity.Text <> "" Then
            RockDens = txtRockDensity.Text
        End If
        If rbtnANFO.Checked = True Then
            ANFODen = txtDensityANFO.Text
            ANFORWS = txtRWSANFO.Text
        End If
        If rbtnEmulsion.Checked = True Then
            IniEmulsDen = txtInitialDensityEmul.Text
            FinEmulsDen = txtFinalDensityEmul.Text
            EmulsRWS = txtRWSEmul.Text
        End If
        If rbtnCartridge.Checked = True Then
            CatrDen = txtDensityCartridge.Text
            CatrDia = txtDiameterCartridge.Text
            CatrRWS = txtRWSCartridge.Text
        End If


        TypeInitiation()
```

```
        RockDeposition()
        RockStructure()
        GRockCategory()
        CalculateValues()
        frmCostInput.Visible = True
        frmOutput.txtMineName.Text = txtMineName.Text()
        frmOutput.txtPitName.Text = txtPitName.Text()

    End Sub

    Public Sub CalculateValues()
        If DrillHDiam < 165 Then
            B = ((0.041 * (DrillHDiam)) - (0.05 + (0.03 * ((BHeight / (Math.Cos(DegOInc * Math.PI /
180)))))))
        Else
            If rbtnANFO.Checked = True Then
                B = (0.012 * (((2 * (ANFODen)) / RockDens) + 1.5) * (DrillHDiam) * Ks * Kd)
            ElseIf rbtnEmulsion.Checked = True Then
                B = (0.012 * (((2 * (FinEmulsDen)) / RockDens) + 1.5) * (DrillHDiam) * Ks * Kd)
            ElseIf rbtnCartridge.Checked = True Then
                B = (0.012 * (((2 * (CatrDen)) / RockDens) + 1.5) * (CatrDia) * Ks * Kd)
            End If
        End If
        frmOutput.txtBurden.Text = Math.Round(B, 1)

        SR = (BHeight / B)
        If cmboTypeInitiation.SelectedIndex = 0 Then
            A = 0
            MsgBox("Please select type of initiation", MsgBoxStyle.Information, "Select Initiation Type")
        End If
        If cmboTypeInitiation.SelectedIndex = 1 Then
            If 1 < SR < 4 Then
                S = ((BHeight + (7 * B)) / 8)
            End If
            If SR >= 4 Then
                S = 1.4 * B
            End If
        ElseIf cmboTypeInitiation.SelectedIndex = 2 Then
            If 1 < SR < 4 Then
                S = ((BHeight + (2 * B)) / 3)
            End If
            If SR >= 4 Then
                S = 2 * B
            End If
        End If
        frmOutput.txtSpacing.Text = Math.Round(S, 1)

        T = (0.7 * B)
        frmOutput.txtStemming.Text = Math.Round(T, 1)

        If RockDens <= 1.6 Then
            J = 0
        ElseIf RockDens > 1.6 Then
            J = (0.3 * B)
        End If
        frmOutput.txtSubDrill.Text = Math.Round(J, 1)

        If DegOInc <= 30 Then
            L = ((BHeight / (Math.Cos(DegOInc * Math.PI / 180))) + J)
        End If
```

```
        frmOutput.txtDrillHLength.Text = Math.Round(L, 1)

        Y = (L - T)
        frmOutput.txtExpCharLength.Text = Math.Round(Y, 1)

        If rbtnANFO.Checked = True Then
            Q1 = ((ANFODen * ((DrillHDiam) ^ 2)) / 1273)
        ElseIf rbtnEmulsion.Checked = True Then
            Q1 = ((FinEmulsDen * ((DrillHDiam) ^ 2)) / 1273)
        ElseIf rbtnCartridge.Checked = True Then
            Q1 = ((CatrDen * ((CatrDia) ^ 2)) / 1273)
        End If
        frmOutput.txtLineCharDens.Text = Math.Round(Q1, 2)

        If rbtnANFO.Checked = True Then
            Q1 = ((ANFODen / 1000) * Math.PI * ((DrillHDiam / 2) ^ 2))
            Q2 = (Q1 * Y)
        ElseIf rbtnEmulsion.Checked = True Then
            Q1 = ((FinEmulsDen / 1000) * Math.PI * ((DrillHDiam / 2) ^ 2))
            Q2 = (Q1 * Y)
        ElseIf rbtnCartridge.Checked = True Then
            Q1 = ((CatrDen / 1000) * Math.PI * ((CatrDia / 2) ^ 2))
            Q2 = (Q1 * Y)
        End If
        frmOutput.txtExploPerHole.Text = Math.Round(Q2, 0)

        Q3 = (Q2 * NoBHoles)
        frmOutput.txtTotalExplo.Text = Math.Round(Q3, 0)
        frmCostInput.txtQTYEXPLOSIVE.Text = Math.Round(Q3, 0)

        V = ((B / (Math.Cos(DegOInc * Math.PI / 180))) * S * BHeight)
        frmOutput.txtVolumePerHole.Text = Math.Round(V, 2)

        Vt = (V * NoBHoles)
        frmOutput.txtTotalVolume.Text = Math.Round(Vt, 2)

        CE = (Q2 / V)
        frmOutput.txtPowderFactor.Text = Math.Round(CE, 2)

        If rbtnANFO.Checked = True Then
            x = (A * (CE ^ -0.8) * ((ANFORWS / 115) ^ -0.63) * (Q2 ^ 0.17))
        ElseIf rbtnEmulsion.Checked = True Then
            x = (A * (CE ^ -0.8) * ((EmulsRWS / 115) ^ -0.63) * (Q2 ^ 0.17))
        ElseIf rbtnCartridge.Checked = True Then
            x = (A * (CE ^ -0.8) * ((CatrRWS / 115) ^ -0.63) * (Q2 ^ 0.17))
        End If
        frmOutput.txtFragmentSize.Text = Math.Round(x, 1)
    End Sub

End Class
```

```
Public Class frmCostInput
    Dim QtyExplosive, UPriceExplosive As Double
    Dim QtyInitiator1, UPriceInitiator1 As Double
    Dim QtyCord1, QtyCord2, QtyCord3, QtyCord4, QtyCord5, QtyCord6, QtyCord7, QtyCord8,
QtyCord9, QtyCord10, QtyCord11, QtyCord12, UPriceCord1, UPriceCord2, UPriceCord3, UPriceCord4,
UPriceCord5, UPriceCord6, UPriceCord7, UPriceCord8, UPriceCord9, UPriceCord10, UPriceCord11,
UPriceCord12 As Double
    Dim P, Pe, Pi1, Pc1, Pc2, Pc3, Pc4, Pc5, Pc6, Pc7, Pc8, Pc9, Pc10, Pc11, Pc12, PpV, PpT As Double

    Private Sub txtUPEXPLOSIVE_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPEXPLOSIVE.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYINITIATOR1_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYINITIATOR1.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD1_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD1.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD2_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD2.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
```

```
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD3_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD3.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD4_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD4.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD5_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD5.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD6_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD6.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub
```

```
    Private Sub txtQTYCORD7_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD7.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD8_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD8.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD9_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD9.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD10_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD10.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD11_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYCORD11.KeyPress
        Dim ch As Char = e.KeyChar
```

```
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtQTYCORD12_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtQTYINI2.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPINITIATOR1_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPINITIATOR1.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD1_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD1.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD2_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD2.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
```

```
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD3_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD3.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD4_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD4.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD5_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD5.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD6_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD6.KeyPress, txtUPCORD11.KeyPress, txtUPCORD10.KeyPress, txtUPCORD9.KeyPress,
txtUPCORD8.KeyPress, txtUPCORD7.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
```

```
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD7_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD7.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD8_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD8.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD9_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD9.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD10_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD10.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = """ Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub
```

```
    Private Sub txtUPCORD11_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPCORD11.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub

    Private Sub txtUPCORD12_KeyPress(sender As Object, e As KeyPressEventArgs) Handles
txtUPINI2.KeyPress
        Dim ch As Char = e.KeyChar
        If Char.IsLetter(ch) Or ch = "!" Or ch = "@" Or ch = "" Or ch = "·" Or ch = "#" Or ch = "$" Or ch =
"%" Or ch = "&" Or ch = "/" Or ch = "¬" Or ch = "(" Or ch = ")" Or ch = "=" Or ch = "?" Or ch = "'" Or
ch = "¿" Or ch = "¡" Or ch = "`" Or ch = "[" Or ch = "^" Or ch = "*" Or ch = "+" Or ch = "]" Or ch = "\"
Or ch = "<" Or ch = ">" Or ch = "-" Or ch = "_" Or ch = "¨" Or ch = "´" Or ch = "{" Or ch = "}" Or ch =
";" Or ch = ":" Then
            'Restricting txtcode to input only digits
            MsgBox("Only numbers are allowed", MsgBoxStyle.Information, "Enter Only Numbers")
            e.Handled = True
        End If
    End Sub


    Private Sub btnDESIGN_Click(sender As Object, e As EventArgs) Handles btnDESIGN.Click
        If txtQTYEXPLOSIVE.Text <> "" Then
            QtyExplosive = txtQTYEXPLOSIVE.Text
        End If
        If txtQTYINITIATOR1.Text <> "" Then
            QtyInitiator1 = txtQTYINITIATOR1.Text
        End If
        If txtQTYCORD1.Text <> "" Then
            QtyCord1 = txtQTYCORD1.Text
        End If
        If txtQTYCORD2.Text <> "" Then
            QtyCord2 = txtQTYCORD2.Text
        End If
        If txtQTYCORD3.Text <> "" Then
            QtyCord3 = txtQTYCORD3.Text
        End If
        If txtQTYCORD4.Text <> "" Then
            QtyCord4 = txtQTYCORD4.Text
        End If
        If txtQTYCORD5.Text <> "" Then
            QtyCord5 = txtQTYCORD5.Text
        End If
        If txtQTYCORD6.Text <> "" Then
            QtyCord6 = txtQTYCORD6.Text
        End If
        If txtQTYCORD7.Text <> "" Then
            QtyCord7 = txtQTYCORD7.Text
        End If
        If txtQTYCORD8.Text <> "" Then
            QtyCord8 = txtQTYCORD8.Text
```

```
    End If
    If txtQTYCORD9.Text <> "" Then
      QtyCord9 = txtQTYCORD9.Text
    End If
    If txtQTYCORD10.Text <> "" Then
      QtyCord10 = txtQTYCORD10.Text
    End If
    If txtQTYCORD11.Text <> "" Then
      QtyCord11 = txtQTYCORD11.Text
    End If
    If txtQTYINI2.Text <> "" Then
      QtyCord12 = txtQTYINI2.Text
    End If
    If txtUPEXPLOSIVE.Text <> "" Then
      UPriceExplosive = txtUPEXPLOSIVE.Text
    End If
    If txtUPINITIATOR1.Text <> "" Then
      UPriceInitiator1 = txtUPINITIATOR1.Text
    End If
    If txtUPCORD1.Text <> "" Then
      UPriceCord1 = txtUPCORD1.Text
    End If
    If txtUPCORD2.Text <> "" Then
      UPriceCord2 = txtUPCORD2.Text
    End If
    If txtUPCORD3.Text <> "" Then
      UPriceCord3 = txtUPCORD3.Text
    End If
    If txtUPCORD4.Text <> "" Then
      UPriceCord4 = txtUPCORD4.Text
    End If
    If txtUPCORD5.Text <> "" Then
      UPriceCord5 = txtUPCORD5.Text
    End If
    If txtUPCORD6.Text <> "" Then
      UPriceCord6 = txtUPCORD6.Text
    End If
    If txtUPCORD7.Text <> "" Then
      UPriceCord7 = txtUPCORD7.Text
    End If
    If txtUPCORD8.Text <> "" Then
      UPriceCord8 = txtUPCORD8.Text
    End If
    If txtUPCORD9.Text <> "" Then
      UPriceCord9 = txtUPCORD9.Text
    End If
    If txtUPCORD10.Text <> "" Then
      UPriceCord10 = txtUPCORD10.Text
    End If
    If txtUPCORD11.Text <> "" Then
      UPriceCord11 = txtUPCORD11.Text
    End If
    If txtUPINI2.Text <> "" Then
      UPriceCord12 = txtUPINI2.Text
    End If

    CostAnalysis()
    frmOutput.Visible = True
End Sub
```

```
    Public Sub CostAnalysis()
        Pe = (QtyExplosive * UPriceExplosive)
        Pi1 = (QtyInitiator1 * UPriceInitiator1)
        Pc1 = (QtyCord1 * UPriceCord1)
        Pc2 = (QtyCord2 * UPriceCord2)
        Pc3 = (QtyCord3 * UPriceCord3)
        Pc4 = (QtyCord4 * UPriceCord4)
        Pc5 = (QtyCord5 * UPriceCord5)
        Pc6 = (QtyCord6 * UPriceCord6)
        Pc7 = (QtyCord7 * UPriceCord7)
        Pc8 = (QtyCord8 * UPriceCord8)
        Pc9 = (QtyCord9 * UPriceCord9)
        Pc10 = (QtyCord10 * UPriceCord10)
        Pc11 = (QtyCord11 * UPriceCord11)
        Pc12 = (QtyCord12 * UPriceCord12)

        P = (Pe + Pi1 + Pc1 + Pc2 + Pc3 + Pc4 + Pc5 + Pc6 + Pc7 + Pc8 + Pc9 + Pc10 + Pc11 + Pc2)
        frmOutput.txtTotalBCost.Text = Math.Round(P, 2)

        PpV = (P / (frmOutput.txtTotalVolume.Text))
        frmOutput.txtCostPerCubeMeter.Text = Math.Round(PpV, 2)

        PpT = (P / ((frmInput.txtRockDensity.Text) * (frmOutput.txtTotalVolume.Text)))
        frmOutput.txtCostPerTon.Text = Math.Round(PpT, 2)

    End Sub

End Class




Public Class frmOutput

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        frmExport.RichTextBox1.Text = "MINE NAME: " + txtMineName.Text + "         " + "PIT NAME: "
+ txtPitName.Text & vbCrLf & _
            "DATE: " + Date.Now.ToLongDateString & vbCrLf & _
            "TIME: " + Date.Now.ToLongTimeString & vbCrLf & vbCrLf & _
       "INPUT PARAMETERS" & vbCrLf & vbCrLf & _
       "BENCH PARAMETERS" & vbCrLf + "Drill Hole Diameter: " + frmInput.txtDrillHDiamter.Text +
" mm" & vbCrLf + "Bench Height: " + frmInput.txtBenchHeight.Text + " m" & vbCrLf + "Vertical Hole
Inclination: " + frmInput.txtBlastHInclination.Text + "°" & vbCrLf & _
        "Number of Blast Holes: " + frmInput.txtNoBlastHoles.Text & vbCrLf + "Type of Initiation: " +
frmInput.cmboTypeInitiation.Text & vbCrLf & _
        "ROCK PARAMETERS" & vbCrLf + "Rock Density: " + frmInput.txtRockDensity.Text + " g/cc"
& vbCrLf + "Rock Deposition: " + frmInput.cmboRockDeposition.Text & vbCrLf + "Rock Structure: " +
frmInput.cmboRockStructure.Text & vbCrLf & _
        "Rock Factor Category: " + frmInput.cmboGRockCategory.Text & vbCrLf & _
        "EXPLOSIVE PARAMETERS" & vbCrLf + "Explosive Selected: " +
frmCostInput.txtDESEXPLOSIVE.Text & vbCrLf & _
        "                  " + "Density (Initial; Final): " + frmInput.txtDensityANFO.Text +
frmInput.txtInitialDensityEmul.Text + "; " + frmInput.txtFinalDensityEmul.Text +
frmInput.txtDensityCartridge.Text + " g/cc" & vbCrLf & _
        "                  " + "Relative Weight Strength: " + frmInput.txtRWSANFO.Text +
frmInput.txtRWSEmul.Text + frmInput.txtRWSCartridge.Text & vbCrLf & _
        "                  " + "Diameter (mm): " + frmInput.txtDiameterCartridge.Text & vbCrLf & vbCrLf & _
        "COST PARAMETERS" & vbCrLf & _
```

```
        "Description; " + "Quantity; " + "Unit Price ($)" & vbCrLf & _
        frmCostInput.txtDESEXPLOSIVE.Text + "; " + frmCostInput.txtQTYEXPLOSIVE.Text + "; " +
frmCostInput.txtUPEXPLOSIVE.Text & vbCrLf & _
        frmCostInput.txtDESINITIATOR1.Text + "; " + frmCostInput.txtQTYINITIATOR1.Text + "; " +
frmCostInput.txtUPINITIATOR1.Text & vbCrLf & _
        frmCostInput.txtDESINI2.Text + "; " + frmCostInput.txtQTYINI2.Text + "; " +
frmCostInput.txtUPINI2.Text & vbCrLf & _
        frmCostInput.txtDESCORD1.Text + "; " + frmCostInput.txtQTYCORD1.Text + "; " +
frmCostInput.txtUPCORD1.Text & vbCrLf & _
        frmCostInput.txtDESCORD2.Text + "; " + frmCostInput.txtQTYCORD2.Text + "; " +
frmCostInput.txtUPCORD2.Text & vbCrLf & _
        frmCostInput.txtDESCORD3.Text + "; " + frmCostInput.txtQTYCORD3.Text + "; " +
frmCostInput.txtUPCORD3.Text & vbCrLf & _
        frmCostInput.txtDESCORD4.Text + "; " + frmCostInput.txtQTYCORD4.Text + "; " +
frmCostInput.txtUPCORD4.Text & vbCrLf & _
        frmCostInput.txtDESCORD5.Text + "; " + frmCostInput.txtQTYCORD5.Text + "; " +
frmCostInput.txtUPCORD5.Text & vbCrLf & _
        frmCostInput.txtDESCORD6.Text + "; " + frmCostInput.txtQTYCORD6.Text + "; " +
frmCostInput.txtUPCORD6.Text & vbCrLf & _
        frmCostInput.txtDESCORD7.Text + "; " + frmCostInput.txtQTYCORD7.Text + "; " +
frmCostInput.txtUPCORD7.Text & vbCrLf & _
        frmCostInput.txtDESCORD8.Text + "; " + frmCostInput.txtQTYCORD8.Text + "; " +
frmCostInput.txtUPCORD8.Text & vbCrLf & _
        frmCostInput.txtDESCORD9.Text + "; " + frmCostInput.txtQTYCORD9.Text + "; " +
frmCostInput.txtUPCORD9.Text & vbCrLf & _
        frmCostInput.txtDESCORD10.Text + "; " + frmCostInput.txtQTYCORD10.Text + "; " +
frmCostInput.txtUPCORD10.Text & vbCrLf & _
        frmCostInput.txtDESCORD11.Text + "; " + frmCostInput.txtQTYCORD11.Text + "; " +
frmCostInput.txtUPCORD11.Text & vbCrLf & _
        "CALCULATED PARAMETERS" & vbCrLf & vbCrLf & _
        "BENCH PARAMETERS" & vbCrLf + "Burden: " + txtBurden.Text + " m" & vbCrLf + "Spacing:
" + txtSpacing.Text + " m" & vbCrLf + "Sub Drill: " + txtSubDrill.Text + " m" & vbCrLf & _
        "Stemming: " + txtStemming.Text + " m" & vbCrLf + "Drill Hole Length: " + txtDrillHLength.Text
+ " m" & vbCrLf & _
        "EXPLOSIVE PARAMETERS" & vbCrLf + "Explosive Charge Length: " +
txtExpCharLength.Text + " m" & vbCrLf + "Linear Charge Density: " + txtLineCharDens.Text + " kg/m"
& vbCrLf + "Explosive Mass per Hole: " + txtExploPerHole.Text + " kg" & vbCrLf & _
        "Total Explosive Mass: " + txtTotalExplo.Text + " kg" & vbCrLf + "Powder Factor: " +
txtPowderFactor.Text + " kg/m³" & vbCrLf & _
        "OUTPUT PARAMETERS" & vbCrLf + "Volume of Blasted Material per Hole: " +
txtVolumePerHole.Text + " m³" & vbCrLf + "Total Volume of Blasted Material: " +
txtTotalVolume.Text + " m³" & vbCrLf + "Average Fragment Size: " + txtFragmentSize.Text + " cm" &
vbCrLf & _
        "COST ANALYSIS" & vbCrLf + "Total Blasting Cost($): " + txtTotalBCost.Text & vbCrLf +
"Blasting Cost($/ton): " + txtCostPerTon.Text & vbCrLf + "Blasting Cost($/m³): " +
txtCostPerCubeMeter.Text
        frmExport.Show()
    End Sub

End Class
```

```
Imports System.IO
Public Class frmExport
   Dim StringToPrint As String


   Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
btnSave.Click
       SaveFileDialog1.Filter = "Word 97-2003 Document(*.doc)|*.doc|Excel Workbook 97-2003
(*.xls)|*.xls| Rich Text Format(*.rtf)|*.rtf|All Files(*.*)|*.*"
       SaveFileDialog1.FileName = Date.Today.Day.ToString + "_" + Date.Today.Month.ToString + "_" +
Date.Today.Year.ToString

       Dim FileWriter As StreamWriter

       Dim results As DialogResult

       results = SaveFileDialog1.ShowDialog


       If results = DialogResult.OK Then

          FileWriter = New System.IO.StreamWriter(SaveFileDialog1.FileName, False)


          FileWriter.Write(RichTextBox1.Text)

          FileWriter.Close()

       End If
   End Sub

   Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
btnPrint.Click
       StringToPrint = RichTextBox1.Text


       If PrintDialog1.ShowDialog() = DialogResult.OK Then

          PrintDocument1.Print()
       End If


   End Sub

   Private Sub PrintDocument1_PrintPage(ByVal sender As System.Object, ByVal e As
System.Drawing.Printing.PrintPageEventArgs) Handles PrintDocument1.PrintPage
       Dim numChars As Integer

       Dim numLines As Integer

       Dim stringForPage As String

       Dim strFormat As New StringFormat()

       Dim PrintFont As Font

       PrintFont = RichTextBox1.Font

       Dim rectDraw As New RectangleF(e.MarginBounds.Left, e.MarginBounds.Top,
e.MarginBounds.Width, e.MarginBounds.Height)
```

```
        Dim sizeMeasure As New SizeF(e.MarginBounds.Width, e.MarginBounds.Height -
PrintFont.GetHeight(e.Graphics))

        strFormat.Trimming = StringTrimming.Word

        e.Graphics.MeasureString(StringToPrint, PrintFont, sizeMeasure, strFormat, numChars, numLines)

        stringForPage = StringToPrint.Substring(0, numChars)

        e.Graphics.DrawString(RichTextBox1.Text, PrintFont, Brushes.Black, rectDraw, strFormat)

        If numChars < StringToPrint.Length Then

            StringToPrint = StringToPrint.Substring(numChars)

            e.HasMorePages = True


        Else

            e.HasMorePages = False
        End If
    End Sub

End Class
```