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EFFECT OF TRENCHING ON BLAST-INDUCED GROUND VIBRATION IN SRI LANKAN METAL QUARRIES

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Department of Earth Resources Engineering

University of Moratuwa
Sri Lanka

June 2017

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EFFECT OF TRENCHING ON BLAST-INDUCED GROUND VIBRATION IN SRI LANKAN METAL QUARRIES

S.A.T.I.Samarakkody

138458c

Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Mining and Mineral Exploration

Department of Earth Resources Engineering

University of Moratuwa

Sri Lanka

June 2019

DECLARATION

I declare that this is my own work and this research does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university or other institute of higher learning and to the best of my knowledge and belief, It does not contain any material previously published or written by another person except were the acknowledgment is made in the text.

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Prof.P.G.R.Dharmaratne Date

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Dr. H.M.S Premasari Date

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Eng.P.V.A.Hemalal Date

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I thank the staff of Maga Engineering (Pvt) Ltd, Arankalle Quarry site for their immense support in completing the experimental analysis related to research.

Last but not the least; I would like to thank my family: my wife, daughter and sons for tolerating me and supporting me spiritually throughout writing this thesis and my life in general.

ABSTRACT

Problems due to ground vibration are a matter of serious concern for the users of explosives. It is not possible to eliminate vibration completely or to contain them at the source. Effort need to be made in controlling them within safe level, without effecting the production schedules and economic viability of the project. When predicted or monitored vibration exceeded the statutory limit, ground vibrations are generally controlled by modifying the blast design parameters. In critical situation, digging a trench has reduced ground vibration. The extent to which it can reduce ground vibration has been examined by field experiments at a open cast quarry mine located at Arankele in Sri Lanka.

After selecting a suitable quarry site at Arankale off Kurunagala in North-Western province of Sri Lanka. Suitable place for blasting face, digging a trench and observation point have been identified.

Vibration measurement were carried out after single shot hole blasting method prior to digging a trench and after digging the trench with variation of depth of drill holes and depth of the trench, at points located just before the trench(A), just after the trench (B) and approximate observation point away from the trench (C).

Average of ten single shot hole blast carried prior to digging trench show ground vibration reduction percentage are 6.326% ,1.23%, 7.023% and 18.309% at B, and 72.262%, 54.474%, 55.183%, and 45.191% at C.

Results after digging the trench show ground vibration reduction percentages are 57.878%, 53.946%, 40.514% and 36.757% at B and 55.509%, 64.787%, 56.848% and 42.382% at C.

Such results indicate, just after the dug trench, ground vibration reduction level is very much higher compared to the results obtained before digging the trench. However considerable deferences have not been observed at the observation point under same condition. The results also show that the percentage of the reduction depend on the trench depth to blast hole depth ratio.

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CHAPTER 01

INTRODUCTION

Ground vibration is a critical aspect of the blasting activity during Open Pit Mining operations. There are numerous instances of building and property damages leading to litigation resulting in quarry production activities as a result of inadequacy in mitigating measures in ground vibration due to blasting activities. The fact that mining companies have been compelled to pay large amounts of money as compensation for resulting damages have discouraged new players entering the industry .

In practice the destruction caused can be minimized by changing the blast design parameters, such as changing number of bore holes, bore hole diameter, depth of a bore hole and charge per delay. Also vibration isolation of structures from ground transmitted waves generated by blasting is an important aspect from the view point of engineering, especially in densely populated areas or in cases where highly sensitive instruments are involved. Active and passive type of vibration isolation are accomplished by barriers which diffract the surface waves radiated from the vibration source and sufficiently reduce their amplitude.

Blast-induced ground vibration level is identified as a major factor limiting large scale blasting, resulting in lower production volumes and lower productivities. Measures should be taken to maintain the ground vibration within the statutory limits given. Environmental issues relating to major construction projects conducted by the Government to achieve high targets in infrastructure development should be given serious attention from the engineering point of view.

Various research programmes have been launched to prove the effect of discontinuities in rocks and excavation of trenches to ground vibration. Devine et al (1965) researched about the effect of fracture planes in propagation of the vibration waves. Gupta et al (1990) could identify a 30 percent reduction in ground vibration by pre-splitting and Worsey et al. (1996)

was able to reveal that pre-splitting is ineffective. Venkatesh et al. (1999) observed a 45 percent reduction in ground vibration levels due to a fault plane. Prakash et al. (2004) carried out a ground vibration monitoring with a trench and a pre-split plane between the blast site and a structure and observed a substantial reduction in vibration magnitudes. Venkatesh et al. (2008) observed percentage of reduction in ground vibration depends on the trench depth to blast hole depth ratio and the horizon of the blast. He also observed that the reduction in vibration is independent of the trench width.

With the support of the previous research, the current research focuses on structural isolation from ground transmitted blast-induced vibration by open trenches under condition of plane strain. The soil medium is assumed to be linear elastic or viscoelastic, homogeneous and isotropic. Horizontally propagating Rayleigh waves or waves generated by the motion of rigid foundation or by surface blasting are considered in this work. The analysis is carried out using numerical methods.

Field experiments were carried out at the Metal Quarry supplying aggregate for the Dambulla -Ambepussa Road Repair operated by MAGA Engineering (Pvt) Ltd. Which location is given below.

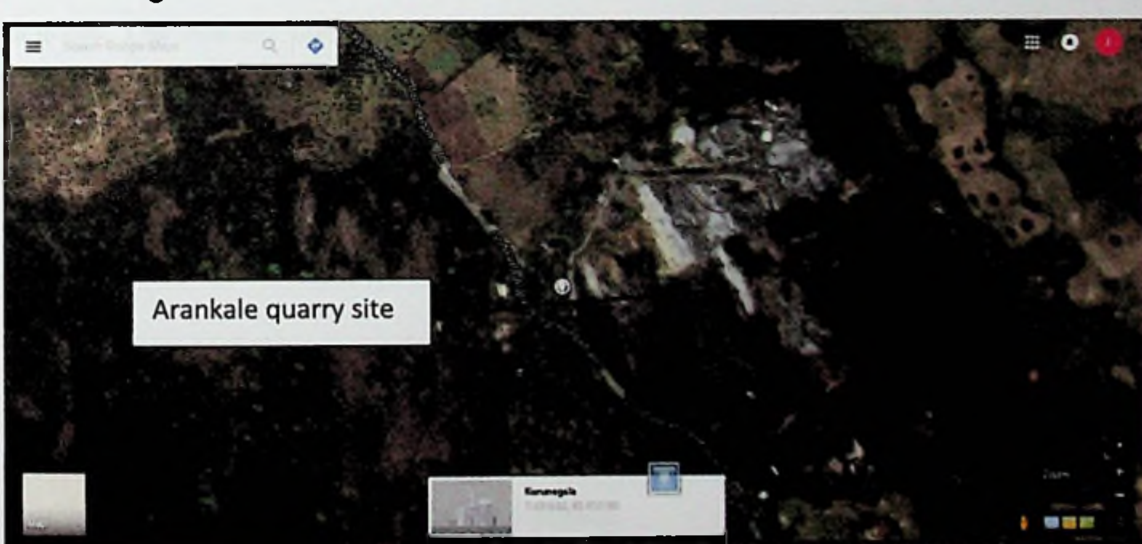


Figure 1. 1 : Arankale quarry site

Figure 1.2 : Test blasting conducted location

The quarry is located at Arankale in the Ganewatta divisional secretarial area in the near western province. Rainy season continues through half of the year and ground water level is not very deep and is at 5-10 feet from the surface during the dry season.

The rock consists of highly fractured weathered layers is a charnokite gneiss and biotite gneiss. The joint pattern is in east- west direction with a dip of approximately 70 to 75 degrees. The blasting operations were carried in the west to east direction to increase the fragmentation and minimize fly rocks.

The significance of the research is the adoption of measures to control blast induced ground vibration increasingly scaly up of blasting levels to achieve a high volume of aggregates with enhanced levels of productivity

The objectives of this research are to study the effect of trenches with varying depth excavated across the blasting point and the point of observation on reducing ground vibration as a result of the blast and also to imply the best trench system to mitigate structural damages around the blasting location.

1.1 Introduction to the work site

In this field work period Arankele Quarry and Plant Complex was selected as field work site which belonging to MAGA Engineering (pvt) Ltd, A-006 road rehabilitation and development project.

The Quarry and plant complex is a "IML - A" category quarry site, with a crusher plant and a mechanical work shop. The plant complex supply Aggregate Base Coarse (ABC) as well as aggregates for the A-006 road rehabilitation and development project from Galewela to Ambepussa.

The aggregates rock is prepared for crushing using blasting activities and followed by hydraulic breaking to reduce the lump size essential for the feeding of the crusher. The crusher plant contain LONG YANG brand a jaw crusher, a cone crusher, two impact crushers and two vibrating screens.

Production of the crusher plant are;

- 0 – 5mm - dust
- 5 – 10 mm - chips
- 10 – 15 mm - ½ inch aggregate
- 15 – 22 mm – ¾ inch aggregate

1.1.1 Location

Arankele Quarry and Plant Complex is located 3 km away from the Bannegamuwa junction which is on the Kumbugate – Wariyapola main road of Kurunegala district. Total area covering the site is 20 acres (see Annex - 2).

1.2.2 Monthly production comparison of the site (December of 2015 –February of 2016)

Table1.1 : Monthly production of the site

Month	ABC (m^3)	0-5mm (m^3)	5-10mm (m^3)	10-15mm (m^3)	15-22mm (m^3)	6"X 9" (m^3)	6"X 4" (m^3)
December_2015	13469.00	1536	461	307	768	663	178.5
January_2016	12200.13	1125	422	281	984	884	69
February_2016	12434.45	1854	371	371	1113	646	25.5

1.2 Quarry

1.2.1 Available mineral resources

There is sufficient rock available in Arankele site to mine and supply for the entire project requirement. The total volume (450000 m^3 insitu volume) of the mineralization is determined using leaner parameters, conducting land surveying (total station), core drilling etc.

1.2.2 Mode of occurrence

How easily and economically rock could be extracted depend on the mode of occurrence of the rock. Mode of occurrencces may be as follows

- Rock out croups standing above the ground level.
- Rock out croup within the overburden
- Rock out croup below the ground surface

In the Arankele quarry the rock out crop stands above the ground level with over burden and vegetation. Rock out croups standing above the ground level is the economical factor.

1.2.3 Quality requirement of aggregates

According to the ICTAD specifications, high quality aggregate should satisfy the following quality requirements given in table. The aggregate which satisfies the following requirements are referred to as quality aggregate.

Table 1.2 : Quality requirement of aggregates

Characteristics	Specification limit
Aggregate Crushing Value(ACV)	Not exceeded 35%
Aggregate Impact Value(AIV)	Not exceeded 30%
Los Angelese Abrasion Value(LAAV)	Less than 40%
Flakiness index(FI)	Not exceeded 35%
Califonia Bearing Ratio(CBR)	Greater than 80%
Water absorption of aggregate	Greater than 2%

1.3 Licenses

Ground vibration and air blast over pressure have been controlled by rules, regulations and conditions through licenses and permits. Number of licenses and permits are required to operate the mining activities in Sri Lanka. Quarry mining carried out by MAGA Engineering (pvt) ltd in the Arankele site, operations under the following licenses and permits given below table.

Table 1.3 : Licenses of the quarry site

License	Issued authority	Valid period
Industrial Mining License(IML-A)	Geological Survey and Mines Bureau (GSMB)	One year
Environmental protection license(EPL)	Provincial environmental authority (North western province)	One year
Trade license	Pradheshiya shaba Ibbagamuwa	One year
Explosive Permit	Deputy explosive controller	6 month

1.3.1 License procedure

Before offering licenses for the mining activities consent of the land owner should be obtained with a clearance certificates from the Grama Niladhari, Divisional Secretary and from Department of Archeology. Also need UDA clearance and IEER or EIA approval.

1.3.2 Industrial Mining License (IML)

Under the Mines & Minerals Act No. 33 of 1992, the GSMB issues four types of licenses.

- Exploration
- Mining
- Trading and Transport(Export).

Two types of mining license are offered in the mining regulations Mining (Licensing) regulation No.1 of 1993.

- **Artisanal Mining License (AML)** Any mining activity which involving manual labor utilizing traditional methods of hand boring. There are two categories

  - **AML-A**
    - The depth of bore hole to be less than 1.5 meters;
    - The production volume to be not less than 100 m^3 and not more than 600 m3 per month;
    - No machinery to be used.
  - **AML-B**
    - The depth of the borehole to be less than 1.5 meters;
    - Production volume to be not exceeding 100 m3 per month;
    - No machinery to be used.

- **Industrial Mining License (IML)** All the large scale mining & quarries using power tools, machinery & sophisticated equipment. There are three categories

  - **IML-A**
    - Blasting method - multi-borehole using delay elements;
    - The depth of the bore hole - more than 3.0 meters;
    - Production volume - more than 1500 m^3 per month;
    - Machinery to be used - track drills, jack hammers, rock breakers, front-end loaders and other machinery.
  - **IML-B**
    - Blasting method - single borehole;
    - Depth of boreholes - not less than 1.5 meters and not more than 3.0 meters;
    - Production volume - between 600 m^3 and not more than 1500 m3 per month;
    - Only jack hammers to be used.

- **IML-C**
    - ➢ Blasting method - single shot-hole;
    - ➢ Depth of the bore hole - less than 1.5 m;
    - ➢ Production volume - should less than 600 m3 per month;
    - ➢ Only jack hammers to be used.

1.3.3 How to apply for the AML and IML?

To obtain the AML or IML for operating quarry mining activities following documents are required by the GSMB.

Table 1.4 : Documents need to obtain AML & IML

Artisanal Mining License (AML)	Industrial Mining License (IML)
• Application form • Copy of the Deed • Copy of the Plan (Not compulsory) • If the applicant is not the land owner, an affidavit should be provided from the land owner or lease agreement.	• Application form • Copy of the Dead • Copy of the Plan • If the applicant is not the land owner and affidavit should be provided from the land owner or a lease agreement. • Economic Viability Report(EVR)

Following steps to be followed to obtain IML

- ❖ Submission of the IML – Application with necessary documents to GSMB
- ❖ Conducting a test blast
- ❖ Preparation and Submission of an Initial Environmental Examination Report (IEER)
- ❖ Evaluation of IEER and approved by the CEA and GSMB

If all steps which mentioned above are satisfied the IML license is approved by the GSMB for a period of one year. License should be renewed each year. The holder should apply for renewal at least 90 days prior to the date of expiry of this license.

1.3.4 Environmental Protection License (EPL)

That license issued by central environmental authority (CEA) all environment impact of the quarry and crusher plant operations are controlled by the license.

Special terms and conditions

- ❖ This license is valid only for operation of metal crusher (cone crusher) at the location.
- ❖ This cone crusher plant activities should be carried out only during daytime (i.e. from 6.00 hrs. to 18.00 hrs.).
- ❖ Transportation activities
- ❖ The developer shall comply with any requirement that would be satisfied from time to time by the PEA-NWP.
- ❖ The developer should ensure that the adequate funds and other facilities, required to monitor the impact of this project are available.
- ❖ A contingency plan should be drawn up to provide immediate redress to families affected by any unforeseen circumstances due to project activities.
- ❖ Degraded and affected areas should be enriched utilizing indigenous plant species.
- ❖ The affected and degraded areas, road ways and dump sites shall be restored or rehabilitated with appropriate landscaping & planning.
- ❖ Safety during operational activities should be ensured.
- ❖ Emergency preparatory plans should be prepared
- ❖ Proper water supply & sanitation facilities shall be made available within the site.
- ❖ The developer shall endeavor to provide employment for as many of the local resident to support the governmental policy to provide employment.
- ❖ The developer should maintain proper records on the progress of the implementation of the project, including the production.
- ❖ Expansion/extension.

The following document should be submitted to the CEA for the license

- Copy of the A category mining license
- Process flow diagram
- Location map
- Certification of incorporation
- Land lease route sketch

1.3.5 Trade License

Trade license can be obtained after obtaining EPL. Copy of "A" category EPL should be submitted to relevant pradeshiya saba with the licensing payment to the pradeshiya to obtain the trade license.

1.3.6 Explosive permit

Explosive license is issued by Deputy Controller of explosive. Explosive permit is granted under the Explosives Act No. 21 0f 1956. Explosive license should be taken before approval of the IML, from the Assistant controller of Explosive (license area). Following documents are required to the explosive license;

- Government Agent approval letter- certifying that the mining area belongs to license holder.
- Police report- certifying the behavior of the license holder

Then explosive license will be issued by Explosive Controller for 6 month period

CHAPTER 02

LITERATURE REVIEW

2.1 Geological features

2.1.1 Strike and Dip Angle

In structural geology the Dip and Strike are used to define the spatial orientation of a bed of rock or other geological formations such as faults and folds. Dip and strike are two angular measurements. Angle of Dip is the deviation of a bedding plane from an imaginary horizontal line. To be more precise Strike is used to define the direction of the dipping bed. Strike is a line formed by the intersection of the tilted bed and an imaginary horizontal surface.

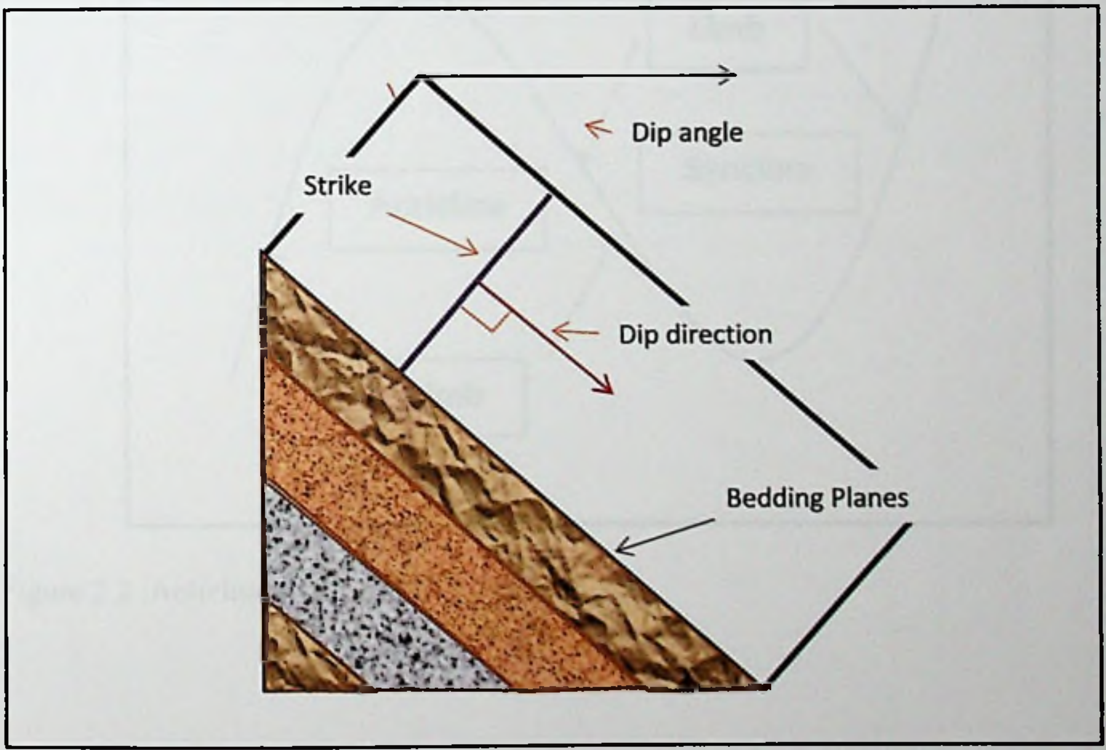


Figure 2.1 :Strike and Dip Angle

2.1.1.1 Folds

When rocks undergo compressional stresses it may deform elastically creating folds. Rocks have a lesser ability to deform plastically under tensional or transform stresses. It can either be an Anticline or a Syncline by analyzing the cross-section of a fold. Commonly these two structures are found as linked structures. Both structures have two limbs each which are formed by dividing with an imaginary axial plane. Other than that a relationship between age and the fold geometry can be established. The sedimentary layers are horizontal before they undergo stresses. When studying age of rocks anticline has its oldest rock layers in the middle and syncline has newest rock layers in the middle.

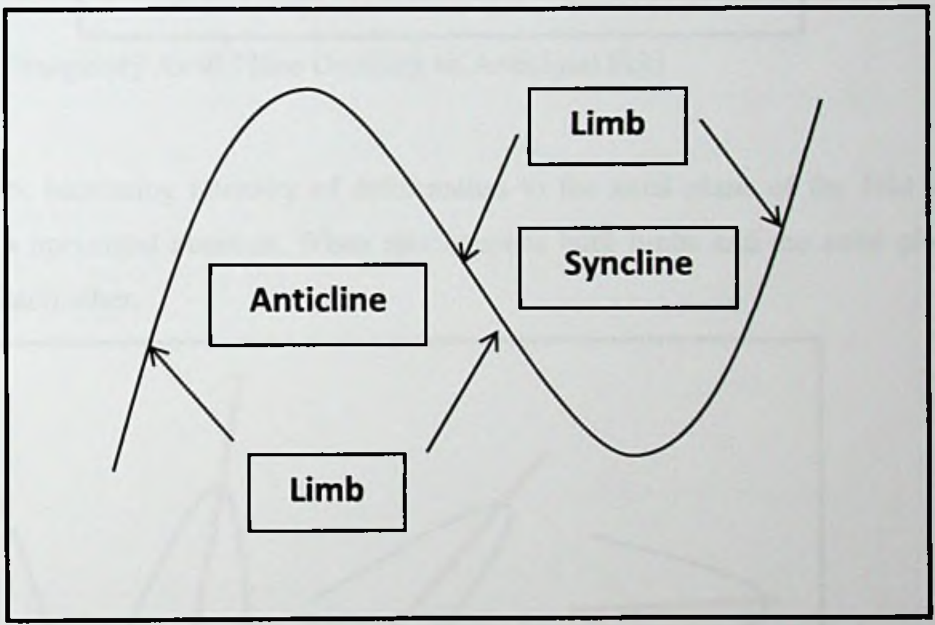


Figure 2.2 :Anticline and Syncline Folds

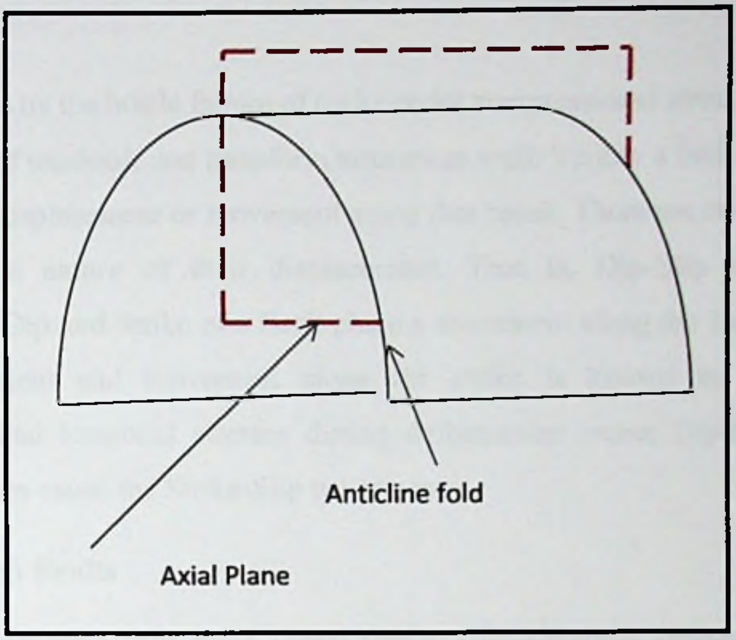


Figure 2.3 :Imaginary Axial Plane Dividing an Anticlinal Fold

However the increasing intensity of deformation to the axial plane of the fold will be pushed to a horizontal position. When this happens both limbs and the axial plane are parallel to each other.

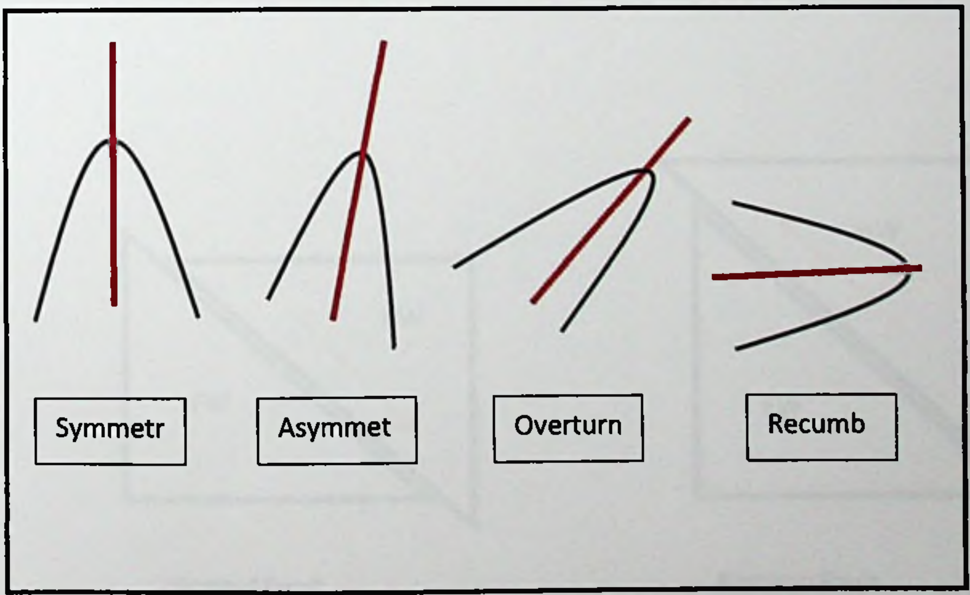


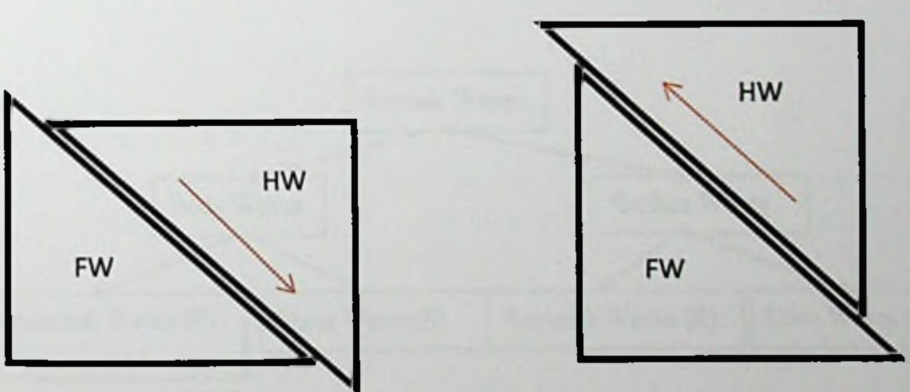
Figure 2.4 :Increasing Intensity of Deformation

2.1.1.2 Faults

Faults are created by the brittle failure of rocks under compressional stress. Other than that faults as a form of tensional and transform stresses as well. Visibly a fault is a break in the rock with some displacement or movement along that break. There are two types of faults classified by the nature of their displacement. That is, Dip-Slip and Strike-Slip. Considering the Dip and Strike of a Fault plane a movement along the Dip is known as a Dip-Slip movement and movement along the strike is known to be Strike-Slip. Compressional and tensional stresses during deformation create Dip-Slip movement. Transform stresses cause the Strike-Slip movement.

2.1.1.2.1 Dip-Slip Faults

There are two sides for a fault plane. Upper side of a fault plane is known as the Hanging Wall and lower side of the plane is known as the Foot Wall. Due to tensional stress, hanging wall can move downward along the fault plane, known as a Normal Fault. Compressional deformation causes the hanging wall to move upward along the plane, known as a Reverse Fault. A special scenario of a reverse fault is Thrust Fault.



Normal Fault

Reverse Fault

Figure 2.5 :Dip-Slip Faults

2.1.1.2.2 Strike-Slip Faults

Brittle deformation under transform forces are known as Strike-Slip faults. They can be identified using geological maps rather than studying a cross-section. A lateral movement along the fault plane takes place during a Strike-Slip movement.

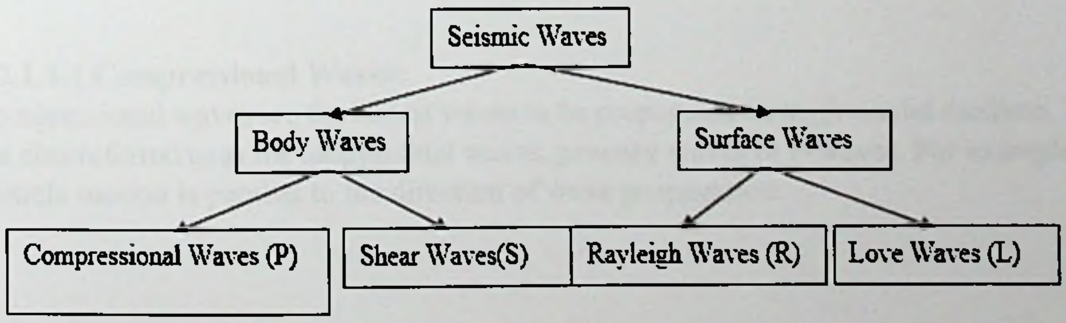
2.1.1.3 Joints and Fractures

Due to tensional, transform or compressional stresses breaking of rocks takes place during deformation. There is no movement along that breakage. Those breaks are known as Joints or Fractures.

2.2 seismic waves

Seismic waves are the waves that move through and on the surface of the earth formed by earthquakes or explosions of rocks. Earth quakes emit two types of waves named as Body waves and Surface Waves.

2.2.1 Waves Classification.



2.2.1.1 Body waves:

Body waves travel through the mass of rock, penetrating down into the interior of the rock mass. There are two kinds of body waves.

- Compressional waves (P)
- Shear waves (S).

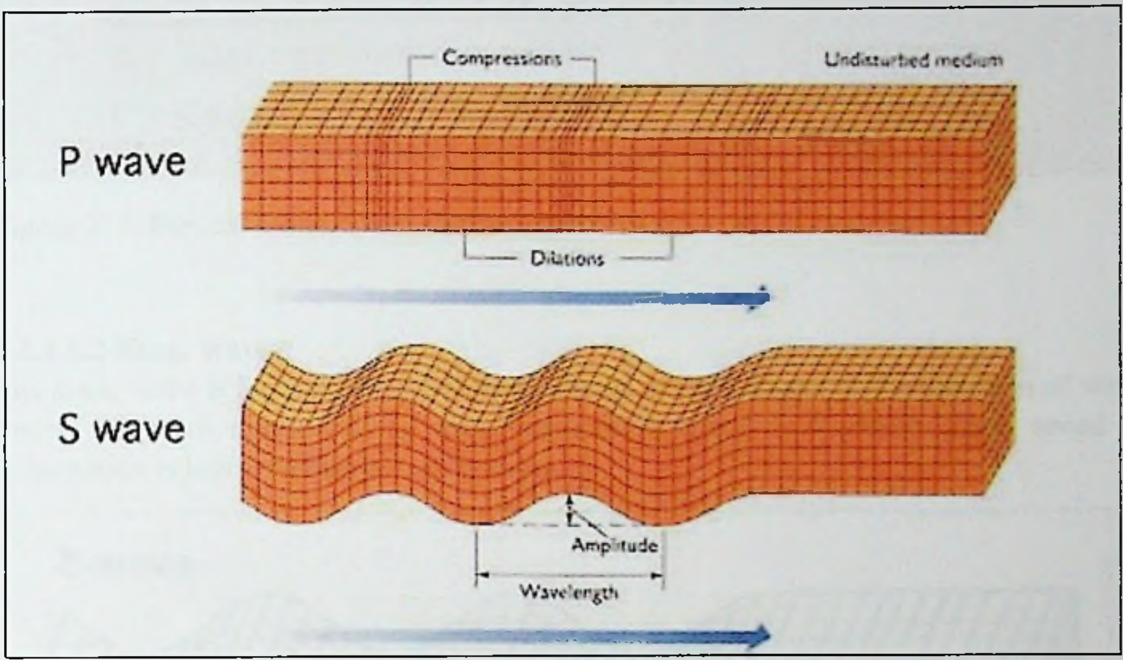


Figure 2.6 :Motion of two types of body waves

2.2.1.1.1 Compressional Waves:

Compressional waves are the fastest waves to be propagated through a solid medium. They are also referred to as the longitudinal waves, primary waves or P-waves. For example, the particle motion is parallel to the direction of wave propagation.

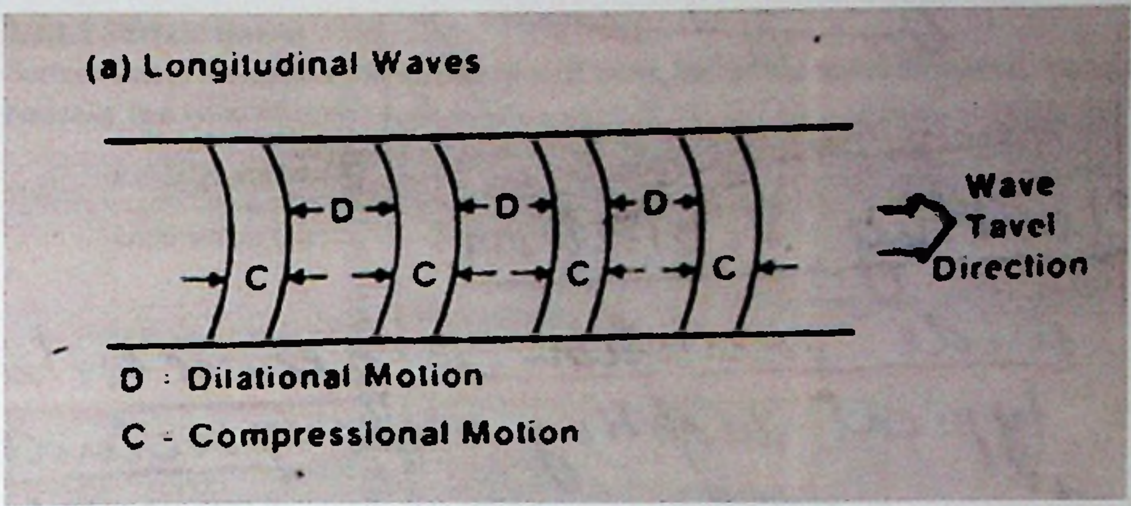


Figure 2. 7 :Partical motion of compressional waves

2.2.1.1.2 Shear waves:

The shear wave is a transverse wave that vibrates at right angles to the direction of wave travel. They are referred to as shear, secondary, shake or S-waves. Their speed of propagation is less then that that of P-waves.

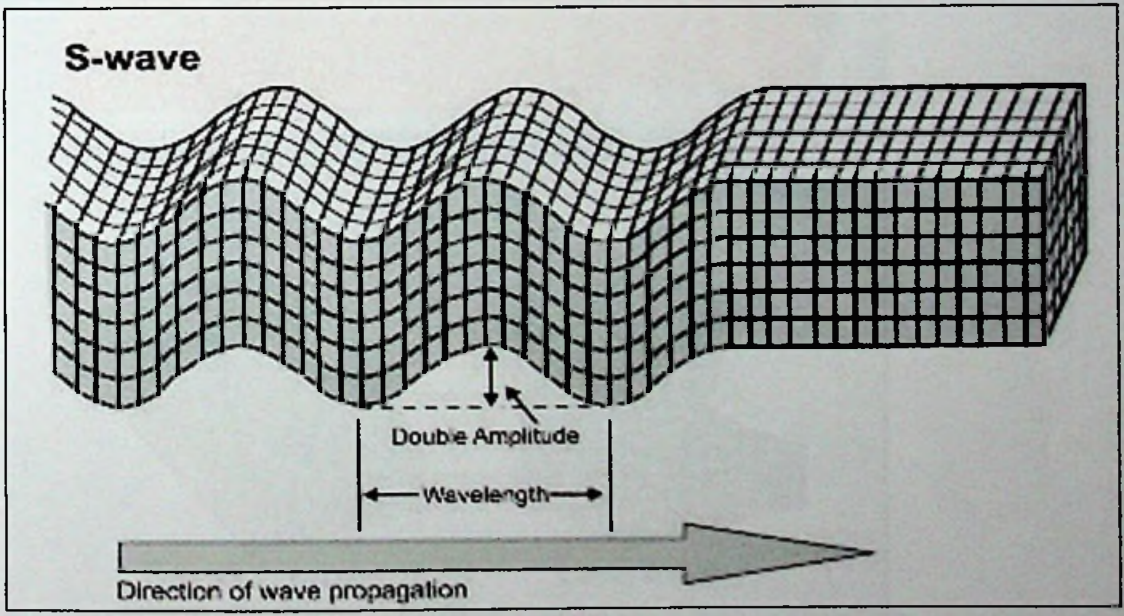


Figure 2.8 :partical motion of shere waves

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2.2.1.2 Surface waves:

Surface waves travel over the surface of rock mass, but do not travel through it. There are basically two types of waves such as.

-Rayleigh waves (R)

-Love waves (L)

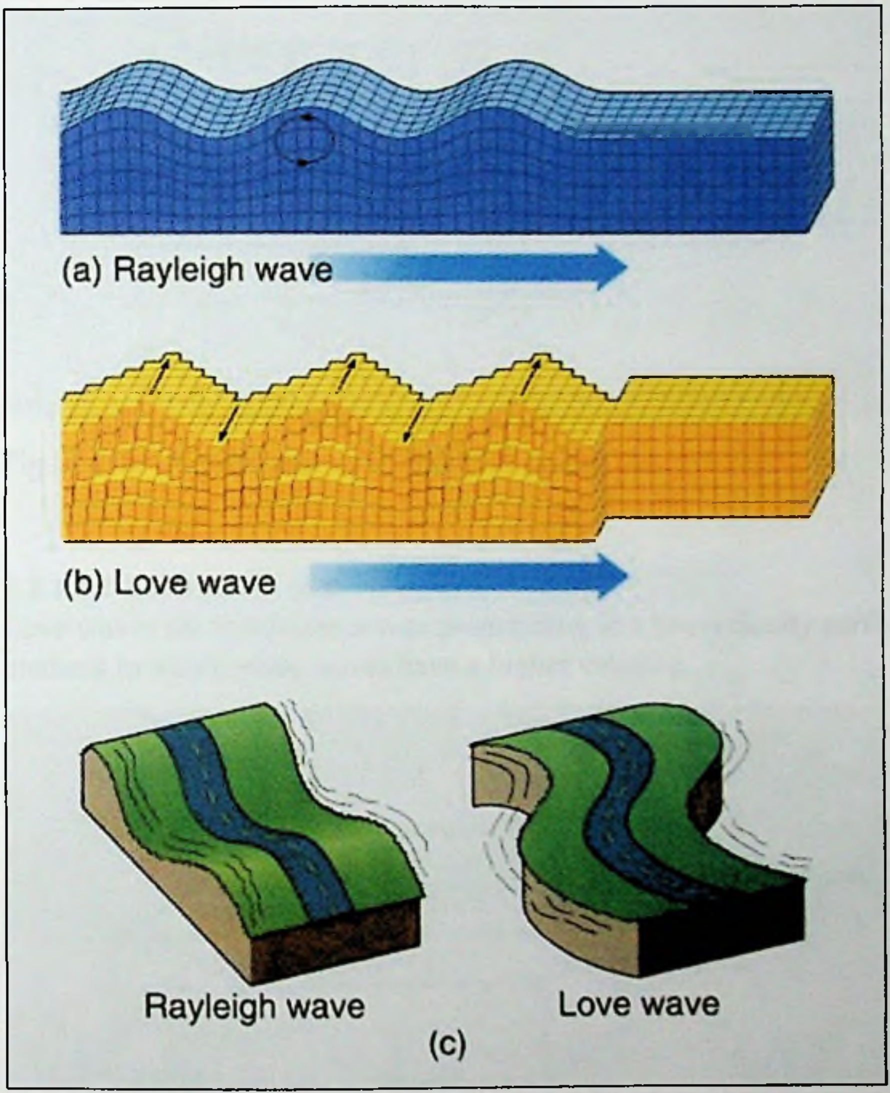

Figure 2.9 :Action of surface wave

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2.2.1.2.1 Rayleigh waves (R):

At interfaces between different media (for instance, at interfaces between ground and air, between ground and water, or between layers of ground of very different elastic characteristics). Rayleigh waves(R) travel only in the free surface. The particle motion is elliptical and always in a vertical plane with respect to the direction of propagation (fig-3-c) and describe a retrograde elliptical motion. The most important of the Rayleigh wave is to damage the surface of the earth. The vertical motion of the particle motion has its maximum just below the surface, but thereafter diminishes relatively rapidly with the depth. It's amplitude decays more slowly with distance travelled than the P and S waves.

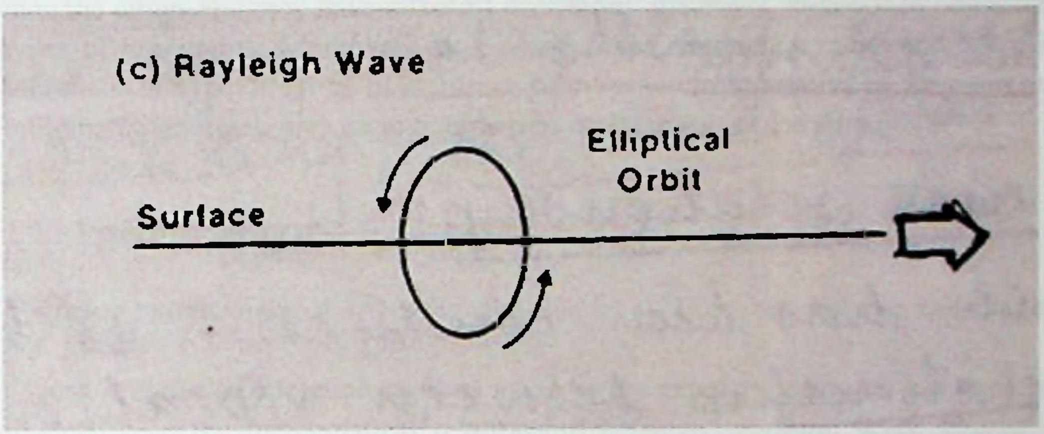


Figure 2.10 :Partical motion of Rayleigh wave

2.2.1.2.2 Love waves (L):

Love waves are transverse waves propagating in a low-velocity surface layer overlying a medium in which static waves have a higher velocity.

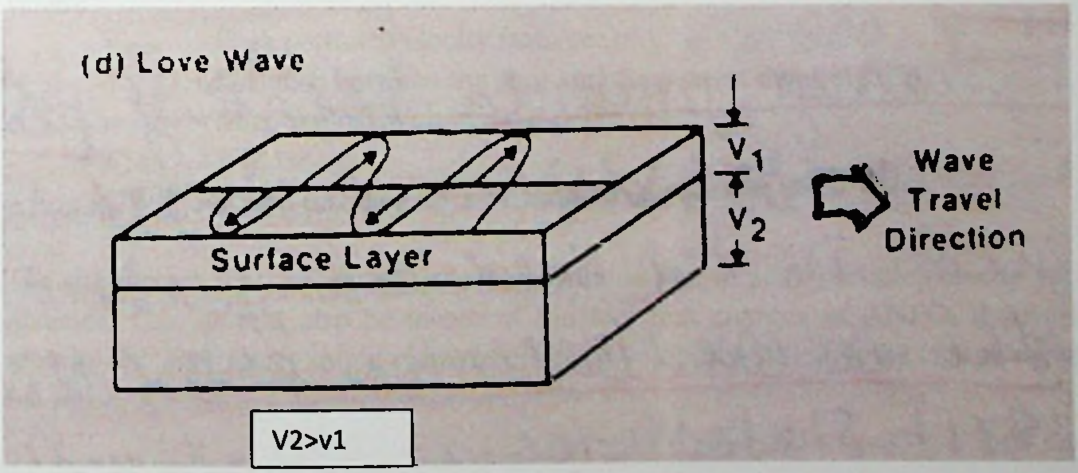


Figure 2. 11 :Partical motion of love wave

2.2.2 Factors affecting vibration:

The wide variation in geometrical and geological conditions on typical blasting sites preludes the solution of ground vibration problems by means of electrodynamic equations. Therefore, the most reliable productions are given by empirical relationships developed as a result of observations of actual blasts.

The connection between vibration and damage to buildings is a complicated one for many reasons. Buildings are constructed in many different ways. Some are more solidly built than the others and they have different dominions, materials, methods of construction, and types of foundation. Moreover, the intensity, type, frequency range and wave length of vibrations and the direction of incidence of the wave front relative to the main axis of the building structure all play an important part in the origin of the damage.

2.2.3 Principal factors:

There are two factors that affect the vibration level. These are distance and charge size.

Charge and distance relationship was made by the extensive research has been conducted to determine the mathematical relationship between vibration level, charge size and distance. An empirical scaling formula relating to peak particle velocity (PPV) to scaled distance has been developed from results obtained in the field by using vibration monitoring equipment.

$$\mathbf{V_{max} = K\,(d\,/W^{1/2})^{-m}.}$$

Where:

- V_{max} - Peak particle velocity (mm/sec)
- d - Distance between the shot and the nearest dwelling. (m)
- w - Max explosive charge per delay (kg)
- K, m - Site factors.
- $d/W^{1/2}$ - Scaled distance for a cylindrical charge ($m/kg^{1/2}$)

The site factors are determined from a logarithmic plot of peak-particle velocity vs. scaled distance. One should also be aware of the fact that charges of ANFO, dynamite, and aluminized TNT slurry might result in different velocities although the charge weights are the same.

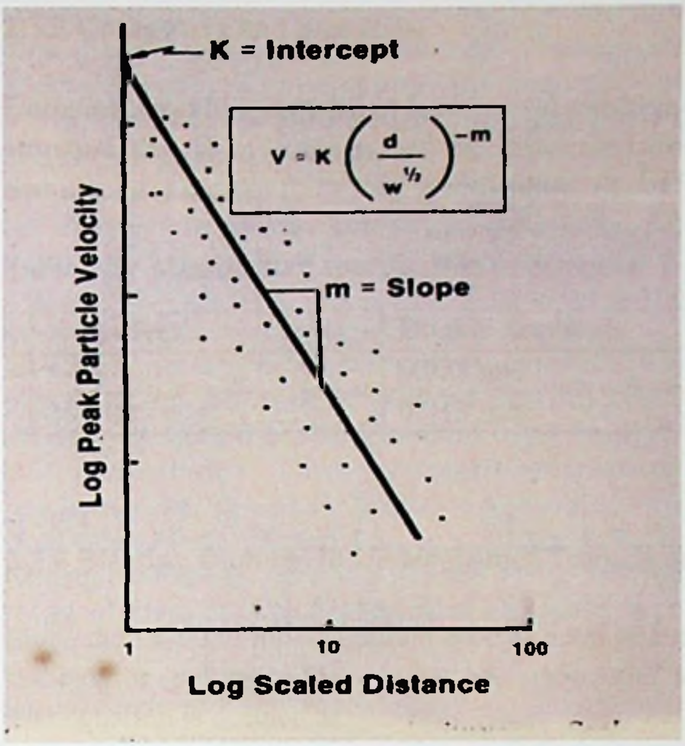


Figure 2.12 :Distance vs velocity

2.3 Blasting standards for non-residential structures;

Can be divided in to two groups in addition to the normal building standards, high level vibration structures and low level vibration sensitive equipment.

2.3.1 Concrete;

Concrete and bridges fall in to the high-level vibration structures. Since concrete acquires about one third it's strength in 72 hours, after this time, a PPV of 1.0 in/sec. is a reasonable maximum until the concrete reaches full strength at 28 days.

2.3.2 Bridges:

Bridges present a variety of sizes, types, construction, age etc.
A steel structure and re-inforced concrete structures would minimally be covered by 2.0 ips (50 mm/sec) and might go up to 5.0 ips (125 mm/sc)

2.3.3 Computers and hospitals:

Computers and hospitals fall in to low-level sensitive category. It is usually not the hospital structure that is of concern but the instrumentation employed therein. One computer manufacturer has the following specification.

Table 2.1 : Manufacture specification of computer

Freq. (Hz)	Double amplitude	Acceleration
5-25	0.025 mm	
25-100	0.013 mm	

2.3.4 Blasting Damage to Underground Tunnels and Rock Masses.

Since the first and most common type of damage that results to underground openings is slabbing or spalling, a formula has been developed to estimate the ppv when this occurs. The equation is defined as:

$$V = 1728\, S_T / \rho_m \,.C_L.$$

Where,

V –Peak particle velocity.(in./Sec.)

S_T – Dynamic tensile strength of the rock mass.(psi)

ρ_m – Masss density of the rock.(lb /ft^3)

C_L – Longitudinal wave velocity in the rock.(ft./Sec.).

CHAPTER 03

METHODOLOGY

3.1 Geology of the arankale rock

Arankele quarry and plant complex is located 3km away from the Bannegamuwa junction on the Kumbugate – Wariyapola main road of Kurunegala district of north-western Province,

Sri Lanka. Total area covering the quarry site is 20 acres (see Annex - 2).Following are some identified geological features of the site.

Figure 3.1 : Fault Plane Location 1

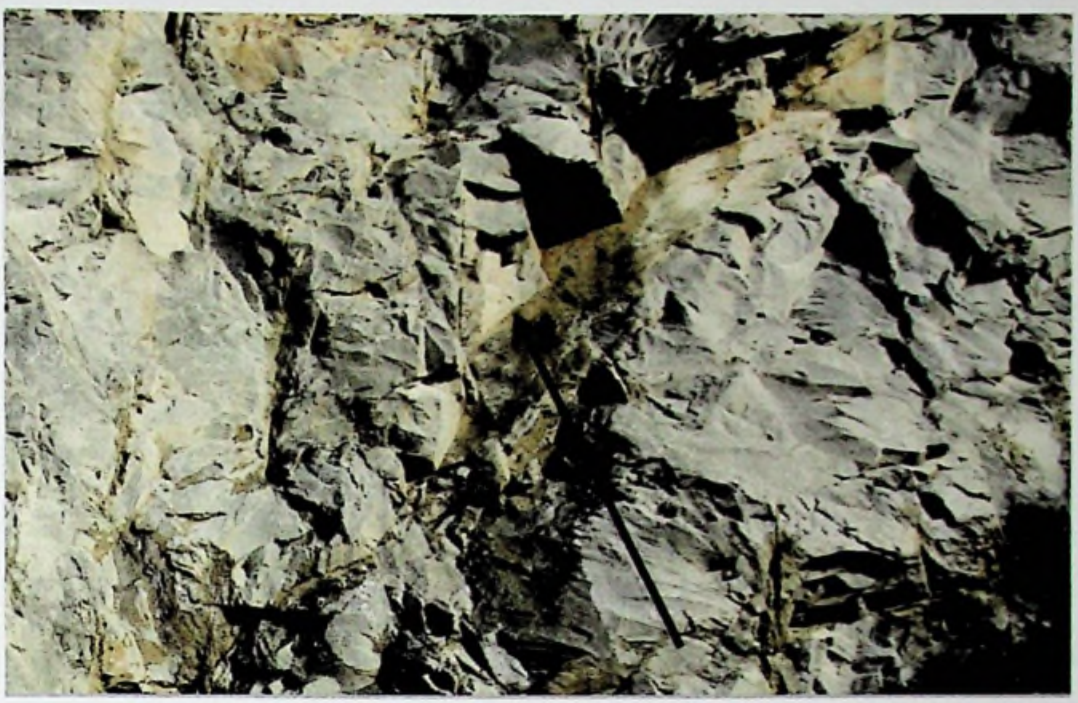


Figure 3.2 : Fault Plane Location 2

Figure 3. 3 :Fractures and Joints

3.2 Rock face preparation for test blasting.

following quarry is properly done in order to achieve accurate testing.

- Mine development
- Drilling
- Blasting
- Secondary Charging
- Blasting & fragmentation by rock breaker
- Loading & transportation

3.2.1 Mine development

The mining method adopted as the Arankele quarry site is open cast benching the preliminary stage. Under the mine development there are several activities to be done. Following activities are conducted at open pit bench blasting mining method in the Arankele quarry site

3.2.1.1 Overburden cleaning

Overburden such as removal top soil, vegetation and weathered rock are cleared before bench preparation for face preparation blasting. Top soil as well as vegetation are removed by using excavator and dump truck while weathered rock is drilled and blasted.

3.2.1.2 Creating the drainage system

A proper site specific drainage system needs dewatering with wast water removal to prevent the soil erosion.

3.2.1.3 Access road and Ramp

Access road and ramp should be efficiently constructed to access the target point, travel and drilling equipment, excavators and dump trucks. Most of these access roads are using Aggregate Base Coarse (ABC) as well as quarry muck. The access road in good condition important to protect tyre of the dump trucks. In some cases, ramps need to be constructed in order to access the target point by using removed top soil as well as weathered rock boulders.

3.2.1.4 Dewatering

Dewatering is important in quarry mining when developing new bench as well as drilling activities. In the particular quarry, water is collected in a sump by using proper drainage system and fracture zone of the rock and it was removed from the quarry by pumping. Removed water is used to spray the access road to the purpose of minimize the dust which is generated by movable machineries.

3.2.2. Drilling

After cleaning the top soil by excavator, drilling activity starts with drilling equipment a combination of track drill and hand drill (jack hammer) is used.

3.2.2.1 Drilling parameters

Following drilling parameters are very important in drilling and blasting activities. It will be directly involved in ground vibration, Air blast and fly rocks.

- Spacing (S)
- Burden (B)
- Hole length
- Hole angle
- Bore hole diameter

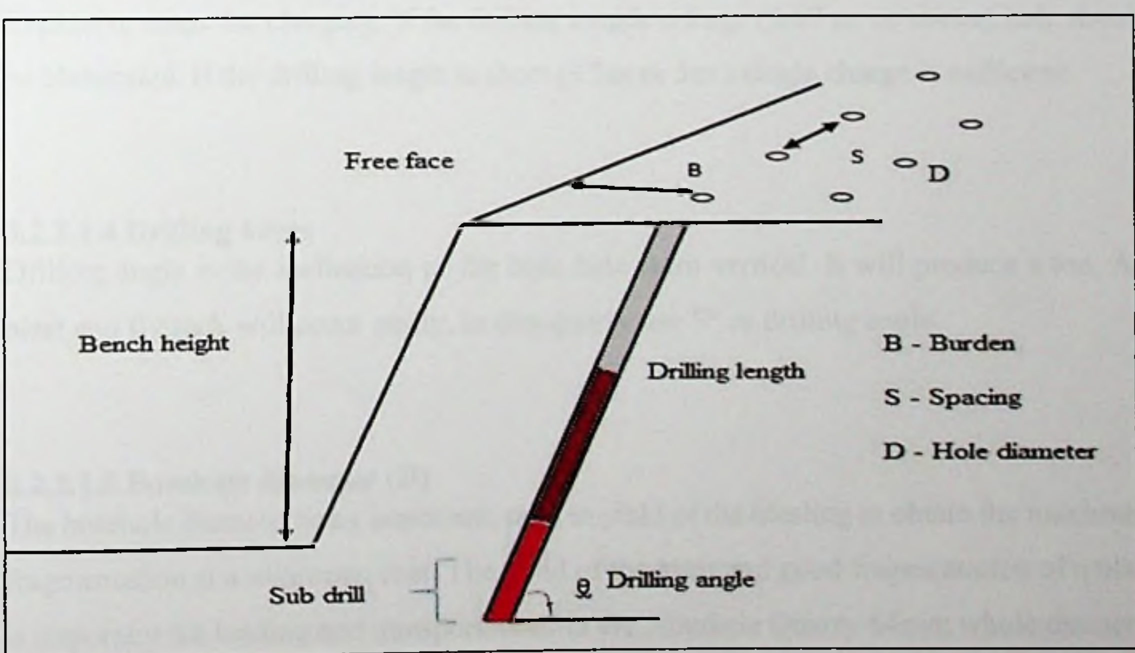


Figure 3. 4 :Drilling parameters

3.2.2.1.1 **Spacing (S)**

Spacing is determined by considering the rock type, whole depth and burden. In general practice spacing to burden ratio ranging from one to two, and for maximum fragmentation, ratio would be 1.15.

3.2.2.1.2 **Burden (B)**

Burden is the most important and critical value in open pit bench design. Effective burden depends on the amount of explosives per hole. Small burden is the cause of fly rocks and air blast with less energy available for the fragmentation. Too large burden results high ground vibration as well as producing big boulders and toe. The Langefors method is commonly used for appropriate burden.

$$B = 45d \quad \text{.......................... Eq. 2.1}$$

B – Burden, d – Diameter of the hole

3.2.2.1.3 **Drilling length**

Depth of the bore hole directly affect the amount of explosives used for the charging. Explosive usage for charging. If the drilling length is large (6.67 m. or above) hole should be elaborated. If the drilling length is short (3.5m or 5m.) single charge is sufficient.

3.2.2.1.4 **Drilling angle**

Drilling angle is the inclination of the bore hole from vertical. It will produce a toe. Air blast and fly rock will occur easily. In this quarry use 5° as drilling angle.

3.2.2.1.5 **Borehole diameter (D)**

The borehole diameter is an important, then to yield of the blasting to obtain the maximum fragmentation at a minimum cost. The yield of the blast and good fragmentation of a blast is important for loading and transportation. In the Arankele Quarry 64mm whole diameter for bench blasting is used, while for the secondary blasting both 40mm and 64mm whole diameter are used.

3.2.2.2 Drilling parameters and approved value by GSMB

Table 3.1 : Drilling prameters and approved value by GSMB

Parameters	Parameter Approved by GSMB
Spacing (S)	2.4m
Burden (B)	2.0m
Drilling length	6m (20feet)
Drilling angle	5°
Diameter of the hole (D)	64mm
No. of holes per round	10

3.2.2.3 Drilling patterns

There are two type of drilling patterns;

1.Square pattern

2.Staggered pattern

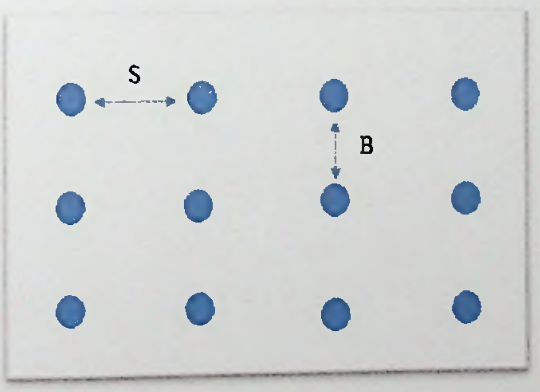


Figure 3.5 :Square pattern

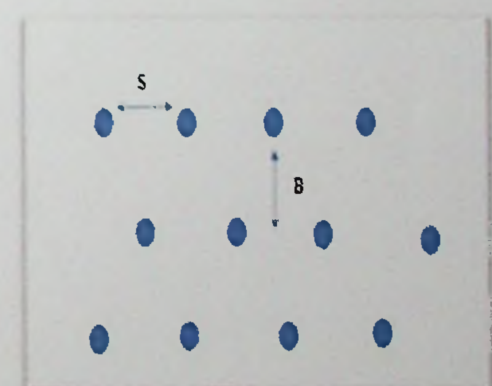


Figure 3.6 : Staggered pattern

In face preparation work, staggered pattern is mainly used for the high fragmentation.

3.2.2.4 Drilling equipment

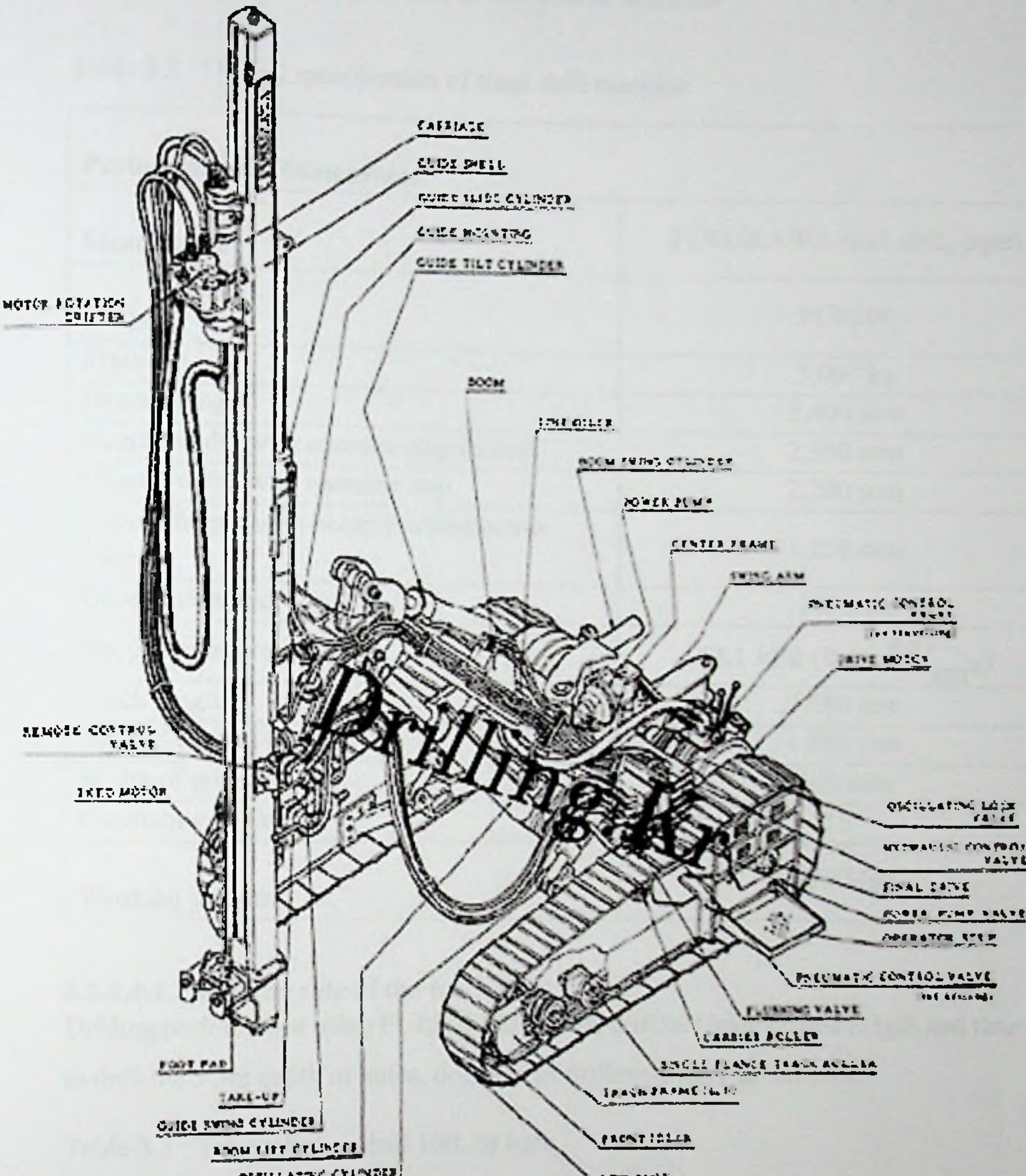
Two types of drillings used in Arankele quarry site are;

- Hand drill (Jack hammer)
- Track drill

Track dill was used for face preparation blasting while the hand drill is used for secondary blasting.

3.2.2.4.1 Track drill

PCR 200 FURUCAWA model track drill machine is used for the drilling activities in this quarry. Airman PDS 655S screw type compressor is use to supply the compressed air to the track drill.



Drilling.Kr

Figure 3.7 :Track drill machine

3.2.2.4.1.1 Overall specification of track drill machine

Table 3.2 : Overall specification of track drill machine

Performance & Dimensions	
Manufacture	FURUKAWA rock drill, japan
Model	PCR200
Mass	5,000 kg
Overall length	5,400 mm
Overall width with operator step folded	2,390 mm
Overall width with operator step	2,280 mm
Overall height with boom lowered below yoke	1,250 mm
Ground clearance	280 mm
Ground pressure	43.1 kPa (0.44 $^{kg}/_{cm^2}$)
Track length	2,580 mm
Ground contact length	1,885 mm
Width of grousers	300 mm
Oscillating angle	15°
Working pressure	>0.5Mpa

3.2.2.4.1.2.Drilling rate of the track drill

Drilling performance using FURUKAWA track drill is. Using drilled length and time taken to drill the 3.3m depth of holes, drill rate of drilling quarry as follows;

Table 3.3 : Time taken to drill 10ft. of hole

Hole No.	1	2	3	4	5	6	7	8
Time (min.)	6.25	6.10	6.15	6.20	6.26	6.21	6.20	6.18

- Total drilling length = $3.33 \times 8 = 26.64\, m$
- Total time (min.) = 49.55 min.
- Drilling rate = $26.64m/_{49.55} =$

$0.54\ ^{m.}/_{min.}\ or\ 1.86\ ^{min.}/_{m.}$

Power source for FURUKAWA track drill is pneumatic power and hydraulic power. Pneumatic power is used for travelling, flushing as well as driving the drifter while hydraulic power is used for boom lift, guide lift, slide, swing, boom swing and for presssure. FURUKAWA track drill machine

- Drill bit
- Extension rod
- Sleeve
- Shank rod

Table 3.4 : Track drill items and their unit prices

Item	Unit price (Rs.)
FURUKAWA 64mm button bit	22,900.00
Extension rod	44,600.00
Sleeve	12,900.00
Shank rod	44,200.00

Table 3.5: Drilling equipment consumption and drilling rate

Month	Item	Item consumption	Drilling length(m)	Drilling length(m)/item
January_2016	Drill bit	08	3148.5	393.56
	Extension rod	04		787.125
	sleeve	04		787.125
	Shank rod	02		1574.25
February_2016	Drill bit	07	2852.35	407.475
	Extension rod	03		950.783
	sleeve	04		713.087
	Shank rod	03		950.783

3.2.2.4.1.3 Maintenance of track drill machine

The maintenance of track drill machine is one of the main responsibilities of Mining Engineer. Following maintenance schedule need to be followed properly.

Table 3.6: Maintenance of track drill machine

Lubricated parts	Description	Lubricating interval	Change oil cycle	Oil and greases	Amount
Drive motor	Air motor	Daily	1000h	DS30	1.0 liters
	Reduction gear	Daily	1000h	DS90	4.0 liters
Track roller		100h	2000h	DS90	0.1 liters
Center frame	Oil reservoir	Daily	2000h	HD68	
	Line oiler	Daily	1000h	DS30	35.0 liters
Power pump	Air motor	Daily	1000h	DS30	0.5 liters
Feed motor	Air motor	Daily	1000h	DS30	0.5 liters
	Reduction gear	Daily	1000h	DS90	2.0 liters
Boom	Pins	Daily	Daily	MP2	
Guide shell	Pins	Daily	Daily	MP2	
	Shaft	Daily	Daily	MP2	
Rod & sleeve			When rod & sleeve connecting	EP2	

3.2.2.4.2 Maintenance of Air compressor

Table 3.7Maintenance of Air compressor

Item	Frequency
Engine oil	Every 500hrs
Engine oil filter	Every 500hrs
Compressor oil filter	Every 500hrs
Inner air filter element	Every 2000hrs
Outer air filter element	Every 500hrs
Oil separator	Every 2000hrs

3.2.2 Blasting

After drilling, charging and blasting are monitored by the mining engineer in proper method. Blasting can be categorized as follows;

- Production blasting
- Secondary blasting
- Chemical fragmentation

Production blasting and secondary blasting is done in the quarry site whereas non explosive chemical fragmentations used for road maintenance.

3.2.2.1 Blasting circuit

In Arankele quarry series connection is used in the blasting circuit. The advantage of this connection is, if any ED is damaged or not connected properly circuit is not completed to blasting.

3.2.2.2 Delay patterns

Two types of delay patterns are used in the Arankele quarry. These patterns are varying with the requirement.

- V – cut pattern
- Row by row pattern

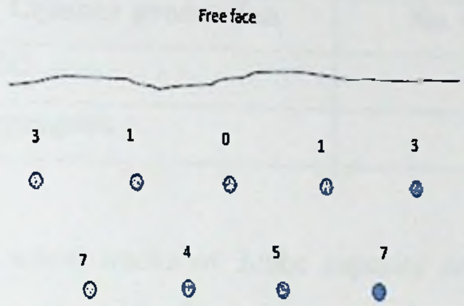


Figure 3.8 : V - cut pattern

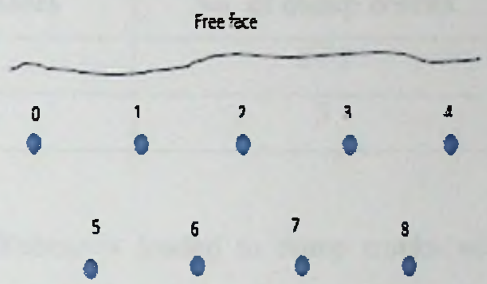


Figure 3.9 : Row by row pattern

3.2.2.3 Powder factor/specific charge

Powder factor value is 0.2 to $0.35^{kg}/_{m^3}$.

$$powder\ factor = \frac{amount\ of\ explosives\ (kg)}{amount\ of\ rock\ production\ (m^3)} \qquad \text{Eq. 2.3}$$

3.2.2.4 Secondary blasting and breaking

- Secondary fragmentation is done with hydraulic breaker attached to an excavator
- Secondary blasting

The selection of size reducing method depends on the size of the boulder. Huge boulders are subjected to secondary blasting whereas hydraulic breaker is used for small boulders. Secondary blasting is used for big boulders as well as toe.

3.2.2.5 Loading and transportation

High ground vibration can be observed in Arankele quarry site, where rubbles is loaded to dump trucks using the excavators. Loading and transport machinery in the Arankele quarry site can be classified as follows;

Table 3.8Loading & transportation machinery

Crusher production	No. of excavators	No. of dump trucks
ABC	2	4 / 5
Aggregates	1	3

Six wheel trucks of 3cube capacity are used. Rubble is loaded to dump trucks with excavators and unloaded to the crusher plant hopper. Access road and ramps be prepared efficiently to prevent fetal accidents and increase the efficiency of the loading and transportation (low cost).

3.3 Testing work (drilling, charging and blasting)

3.3.1. Drilling

After cleaning face of rock by using excavator, drilling activity was done by using the drilling equipment of hand drill (jack hammer). Drilling is the first step this testing. Bore hole locations were selected as isolate each one from other blasting.

3.3.1.1 Hand drill (Jack hammer)

Y26 (weight of the jack hammer is 26Kg) type of jack hammer used for the drilling purpose. They are using with diameters 32mm, 34mm,36mm,38mm,40mm and rods with lengths of 2.5ft, 5ft, 8ft, 10ft, 13ft for jack hammer and DS40 oil is used as the oiler for the jack hammer.

3.3.1.2 Drilling length

Drilling length of a bore hole directly affect the amount of explosives used for the charging. Explosive usage for the charging depends mainly on the length of the bore hole. Whole depths are varying 1.0 m to 2.5 m in this testing.

3.3.1.3 Drilling angle

It will produce a toe. Air blast and fly rock were occur easily. In this testing use 4 degree as drilling angle.

3.3.1.4 Borehole diameter (D)

The borehole diameter is important, to offer a good in yield of the blasting to obtain the maximum fragmentation at a minimum cost. The yield of the blasting and good fragmentation of the blasting are important to the loading and transportation. In this project used 36mm to 42mm whole diameter bits.

3.3.2 Charging

Following explosives and accessories are using for the charging activity in test blasting

- ED (Electric Detonator) – initiator
- Water gel – prime charge
- ANFO – column charge

3.3.2.1 Electric Detonator (ED)

Short delay (millisecond) Electric Detonators are used as the initiator in this quarry as guided by the mining license.

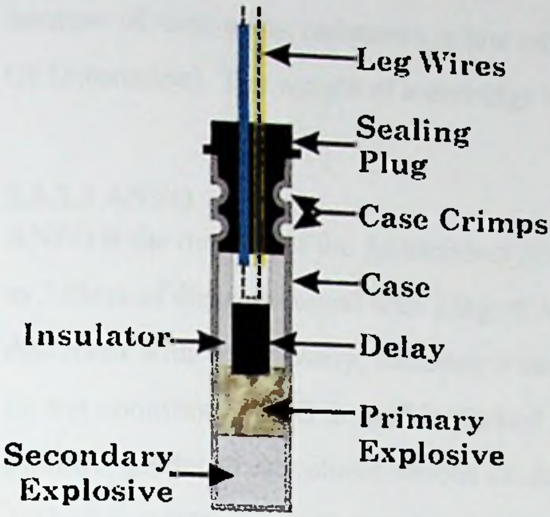


Figure 3.10 :Electric detonator

3.3.2.1.1 Specification of ED

Table 3.9: Specification of ED

Shell	Aluminum
Shell length	50 to 60 mm
Lead wire colour	White and red
Lead wire length	4.0 mtrs
Delay Nos.	0 to 9
Delay interval	25 millisecond
Resistance	3 – 10 Ω

3.3.2.2 Water gel

Water gel is used as the prime charge which is originally developed as a safe alternative to the NG – based explosives in charging activity. It is a mixture of oxidizing salts, a fuel sensitizer and water (usually about 15%). Water gel is used mainly in water condition areas because of their water resistance is low compare with dynamite and high VOD (Velocity Of Detonation). The weight of a cartridge is about 135g.

3.3.2.3 ANFO

ANFO is the mixture of the Ammonium Nitrate prills and Fuel Oil (diesel). In practical 2.5 to 3 liters of diesel is mixed with 25kg of Ammonium Nitrate to produce ANFO. It can be dissolved with water easily, therefore it cannot be used in water and with wet conditions. In wet condition ANFO is used in packed form. If the Fuel Oil is very low percentage in mixture, produce rust colored nitrous oxide fumes in dry hole. ANFO having an excess of fuel oil in mixture in detrimental to the maximum energy output in mixture. In order to the optimum energy release 94.5% Ammonium Nitrate should mix with 5.5% Fuel Oil.

3.3.2.4 Charging a drill hole

- Before charging the bore hole, it should be cleaned to remove the water and small rock particles from borehole.
- Primer is made with water gel and ED and inserted into the drill hole. Selected quantity of water gel is used for the drill hole (according to the design).
- Column charge (ANFO) is added to the hole according to the design. When the cleaning the bore hole (blowing) sometime water cannot be removed from the hole. In this situation ANFO will be filled in packed form.
- Finally stemming material should be filled properly up to the top level. In Arankele quarry dust (0 – 5mm) and chips (5 – 10mm) are used as the stemming material.

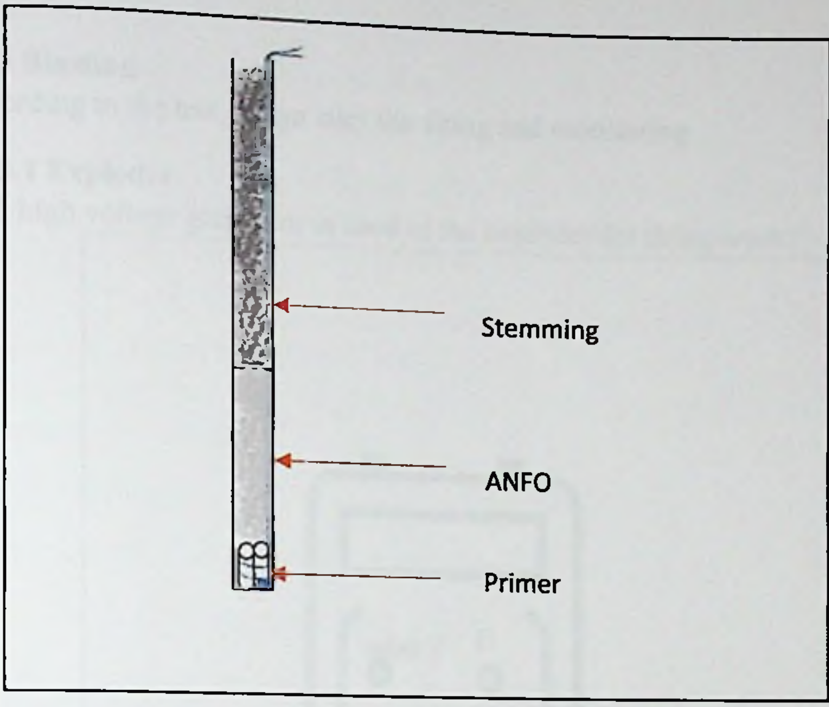


Figure 3.11 :Charging a borehole

3.3.2.5 Stemming distance (T)

Stemming is used to confine the explosive i.e. high explosive charge functions properly and release maximum energy. The charge should be confined in the bore hole in order to control air blast and fly rock.

Common relationship for stemming distance (T) is,

$$T = 0.7 \times B \qquad \text{Eq. 2.2}$$

B – Burden

But the stemming distance needs to be adjusted according to the variation in the rock as well.

3.3.3 Blasting

According to the test design start the firing and monitoring .

3.3.3.1 Exploder

D.C. high voltage generator is used as the exploder for firing work.

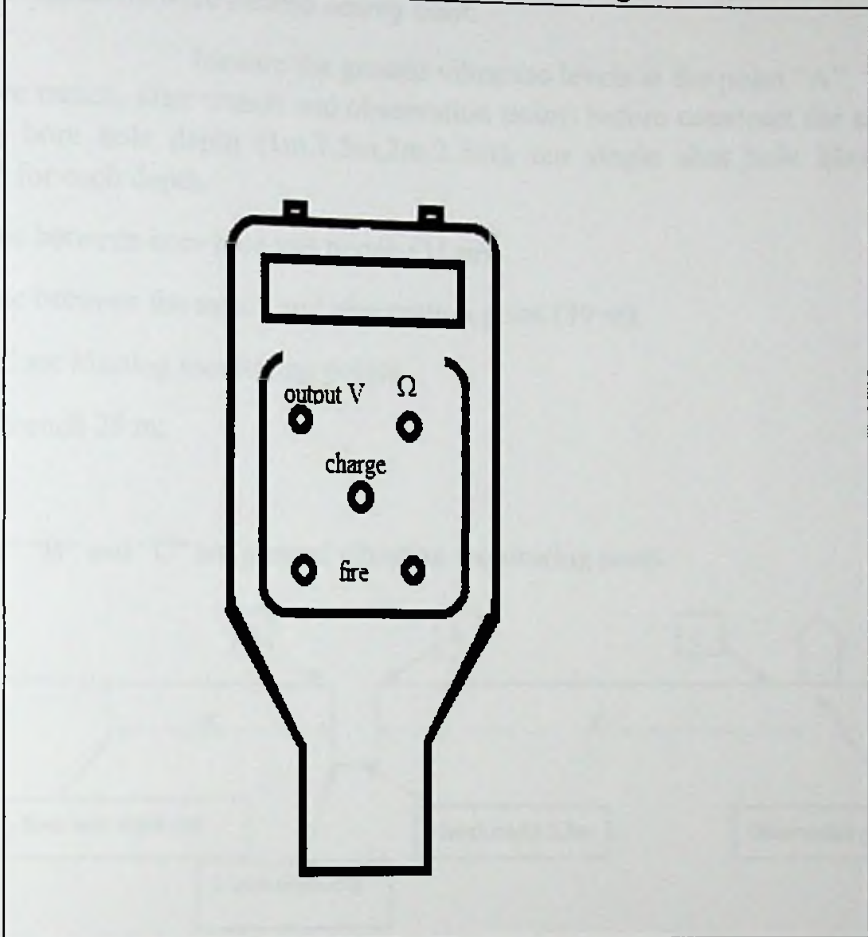


Figure 3. 12 Exploder

Specification of exploder

- Manufacturer – L.M.C. Enterprises
- Discharge voltage – 1000 V
- Serial No. – LG100042HR43

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3.4 Design the trench and bore holes

Efect of trenching on blast induced ground vibration in sri lanka metal quarries adopted in the research programme to control the ground vibration is based on the seismic propagated regulators were located nearby blast.

Mesure the ground vibration levels at the point "A", "B", and "C" (before trench, after trench and observation point) before construct the trench by increasing bore hole depth (1m,1.5m,2m,2.5m), ten single shot hole blasting are conducted for each depth.

X- Distance between bore hole and trench (31 m).

Y- Distance between the trench and observation point (39 m).

A, B and C are blasting monitoring points.

Length of trench 28 m.

"A" "B" and "C" are ground vibration monitoring point

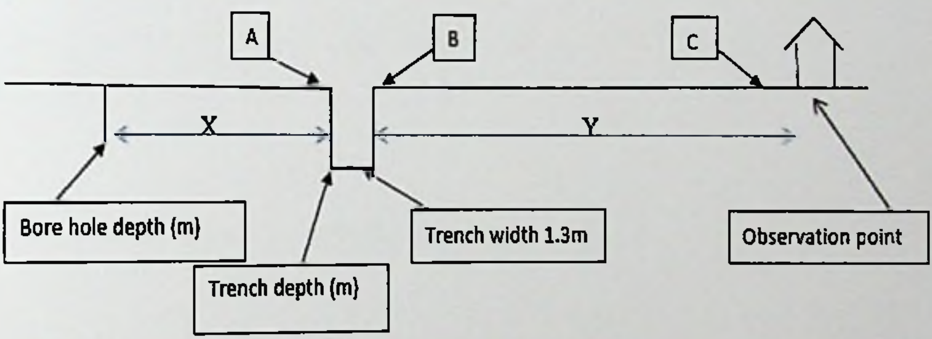

Figure 3. 13: Design the trench and bore holes for testing

After that, Measure the ground vibration level at the point "A", "B", and "C" (before trench, after trench and observation point) after construct the trench by increasing bore hole depth (1m,1.5m,2m,2.5m) and trench depth (1.5m,2m,2.5m,3m) significantly, ten single shot hole blasting are conducted for each depth

Trench length is increased for Active Isolation, where the vibrations are reduced by a trench in the direct path close to the excitation source. And Trench length is increasd for Passive Isolation, where the vibrations are reduced by a trench in the direct path close to the point of observation. Over 50 measurements will be carried out using Blasting monitor with a fixed charge level of explosives.

CHAPTER 04

RESULTS AND DISCUSSION.

Before construct the trench
"A" "B" and "C" are ground vibration monitoring points

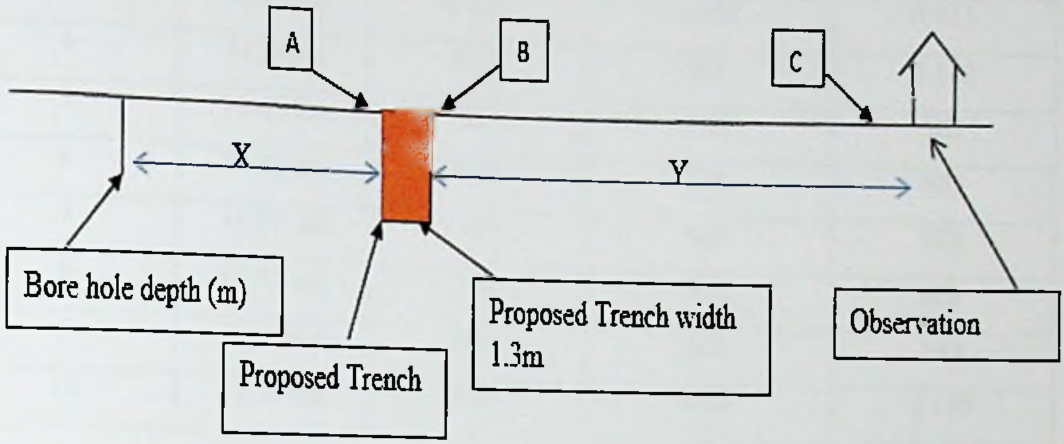

Figure 4.1 :Ground vibration monitoring points

4.1 Bore holes depth 1m and no trench (set-1)

Trench	: No		
Date	: 2015/11/21		
Bore whole depth	: 1 m		
No of holes	: 10		
Explosive quantity per one hole-	: (01). Electric detonater	: 01	
	(02). Water gel	: 62.5g	
	(03). ANFO	: 150g	

Table 4.1 : Ground vibration readings for 1m depth bore holes (without trench)

Blasting sequence	Time	Readings(mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	11.18am	ND	ND	ND
2	11.20 am	0.456	0.333	0.112
3	11.22 am	0.191	0.232	0.113
4	11.24am	0.56	0.5	0.112
5	11.26 am	ND	ND	ND
6	11.28 am	0.33	0.3	ND
7	11.29 am	ND	ND	ND
8	11.31 am	ND	ND	ND
9	11.33am	ND	ND	ND
10	11.36 am	0.52	0.56	0.119

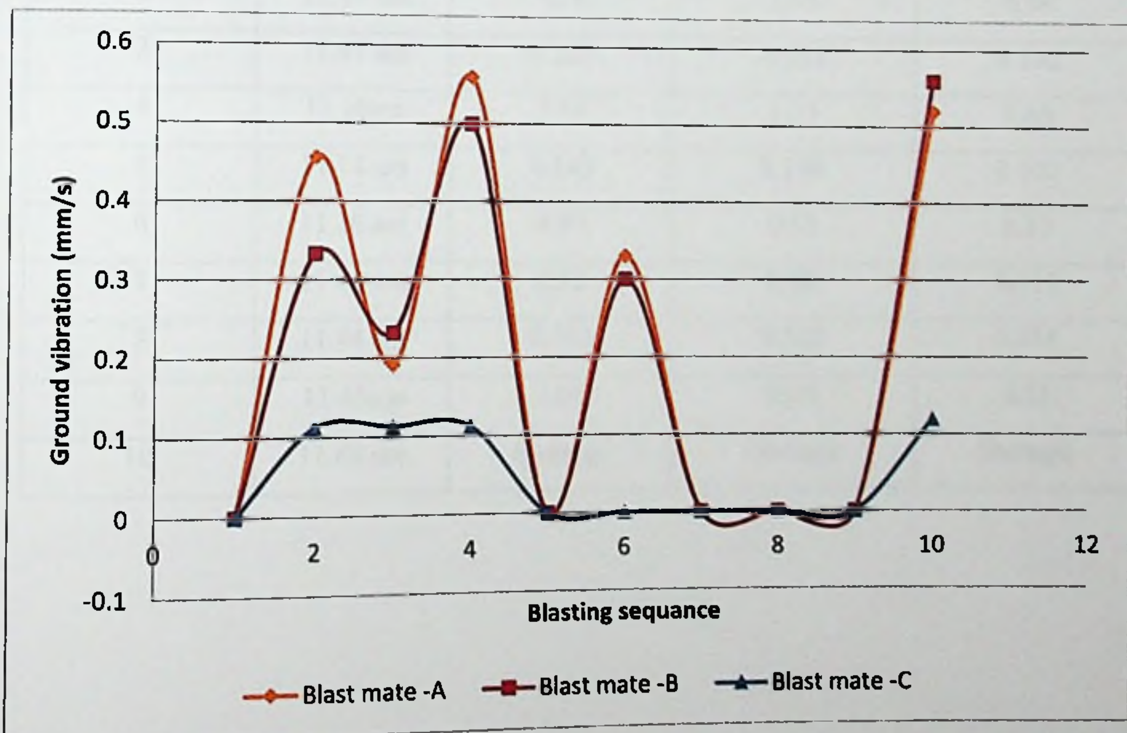

Figure 4.2 :Ground vibration variation vs blasting sequence (1m bore holes,no trench)

According to the results 1st, 5th,7th,8th and 9th blasting were not fully detected at point A,B and C. 6th blasting was not detected at point C.

4.2 Bore hole depth 1.5m and no trench (set-2)

Trench : No

Date : 2015/11/21

Bore whole depth : 1.5 m

No of holes : 10

Explosive quantity per one hole : (01). Electric detonater : 01

(02). Water gel : 125g

(03). ANFO : 300g

Table 4. 2 : Ground vibration readings for 1.5m depth bore holes (without trench)

Blasting sequence	Time	Readings(mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	11.03 am	1.76	1.14	0.501
2	11.05 am	1.56	1.45	0.98
3	11.07 am	0.225	0.958	0.102
4	11.10am	1.34	1.35	0.65
5	11.14 am	0.143	0.149	0.102
6	11.16 am	0.87	0.53	0.13
7	11.40 am	0.52	0.56	0.119
8	11.44 am	0.582	0.532	0.551
9	11.45am	1.05	0.98	0.53
10	11.48 am	Damage	Damage	Damage

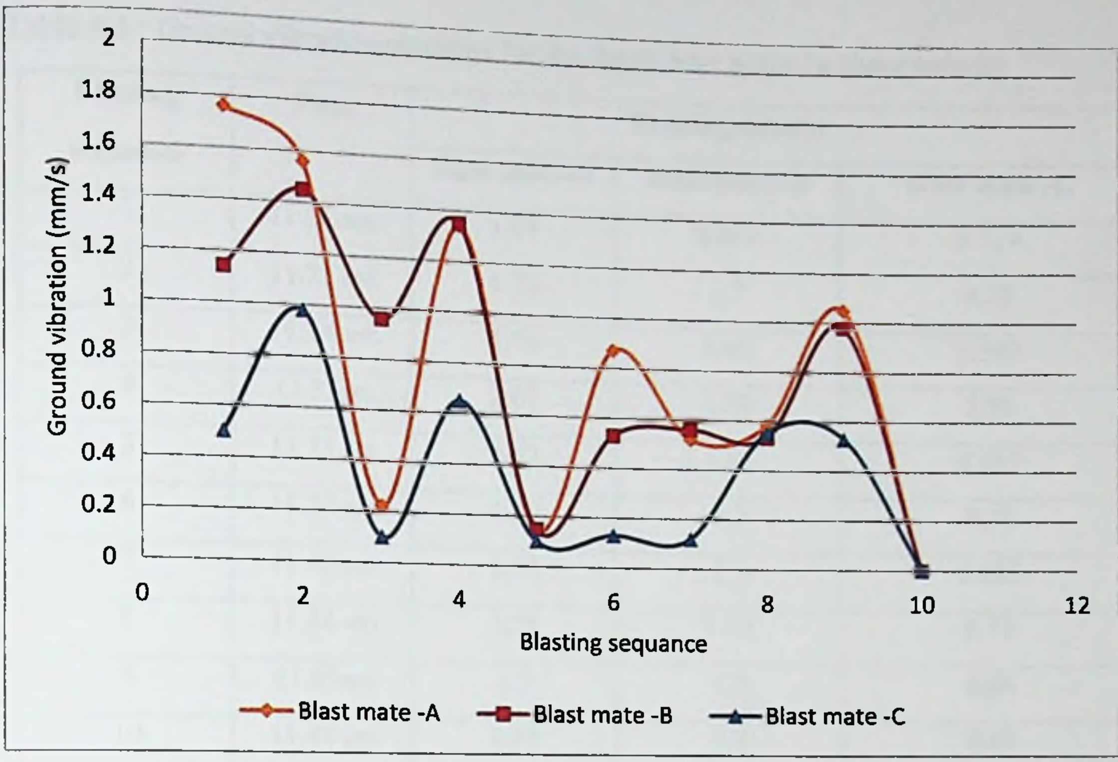

Figure 4.3:Ground vibration variation vs blasting sequence (1.5m bore holes,no trench)

Here, 10th bore hole was damaged due to 9th one. point A reading was less than point B reading in the 3rd and 7th blasting.

4.3 Bore hole depth 2m and no trench (set-3)

Trench	: No		
Date	: 2015/12/10		
Bore whole depth	:2m		
No of holes	:10		
Explosive quantity per one hole	:(01). Electric detonater	: 01	
	(02). Water gel	:125g	
	(03). ANFO	:634g	

Table 4.3 : Ground vibration readings for 2m depth bore holes (without trench)

Blasting sequence	Time	Readings(mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	11.21 am	1.09	0.862	0.719
2	11.23 am	1.76	1.7	0.78
3	11.24 am	1.76	1.66	0.569
4	11.33am	2.01	1.99	0.98
5	11.35 am	1.72	1.47	0.487
6	11.37 am	1.23	1.3	0.43
7	11.40 am	1.73	1.2	0.885
8	11.44 am	1.56	1.63	0.72
9	11.45am	1.2	1.2	0.68
10	11.48 am	0.89	0.9	0.45

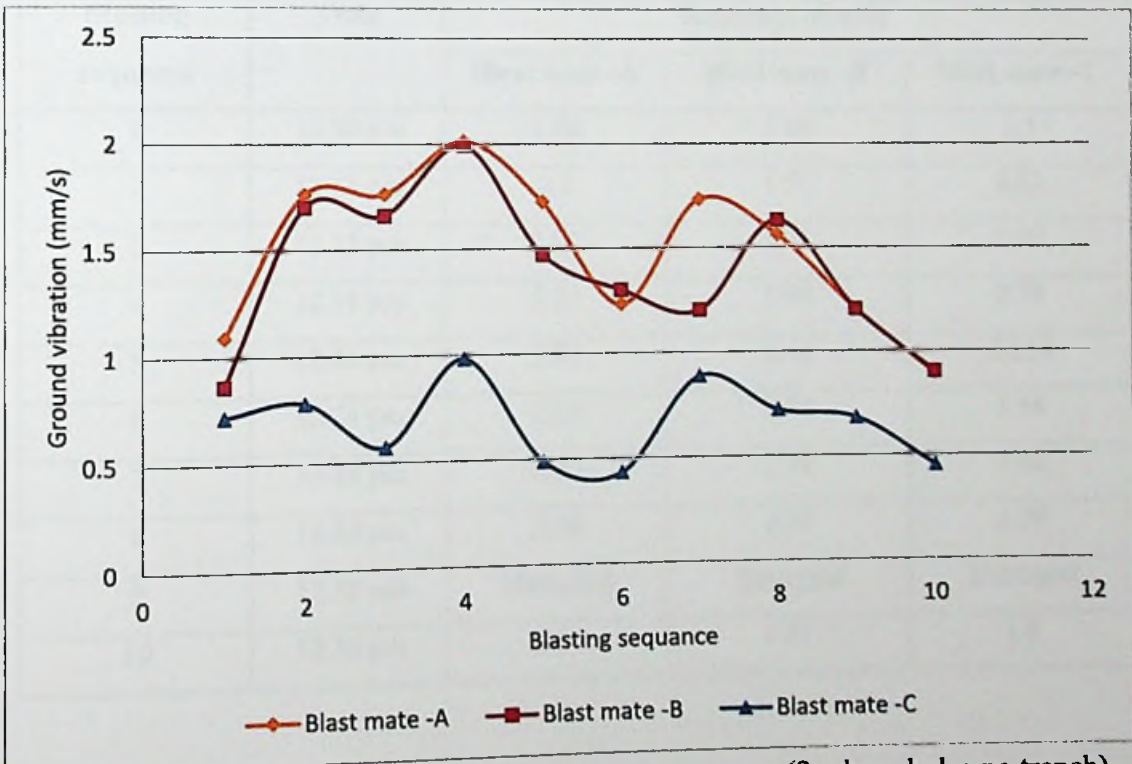

Figure 4.4 : Ground vibration variation vs blasting sequence (2m bore holes,no trench)

Though, ground vibration variations are not considerable deference in between both side of the proposed trench (A and B), which is very low at the observation point.

4.4 Bore hole depth 2.5m and no trench (set-4)

Trench	: No		
Date	:2015/12/10		
Bore whole depth	:2.5 m		
No of holes	:10		
Explosive quantity per one hole	:(01). Electric detonater	: 01
	(02). Water gel	:125g
	(03). ANFO	:850g

Table 4.4 : Ground vibration readings for 2.5m depth bore holes (without trench)

Blasting sequence	Time	Readings (mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	12.10 pm	1.96	1.99	1.3
2	12.13 pm	2.3	1.56	0.63
3	12.15 pm	2.29	1.02	1.59
4	12.18 pm	2.21	1.89	0.79
5	12.22 pm	2.82	2.42	0.814
6	12.24 pm	2.56	2.43	1.54
7	12.28 pm	3.33	2.79	2.02
8	12.30 pm	2.86	2.36	1.78
9	12.32 pm	Damaged	Damaged	Damaged
10	12.33 pm	2.04	1.81	1.8

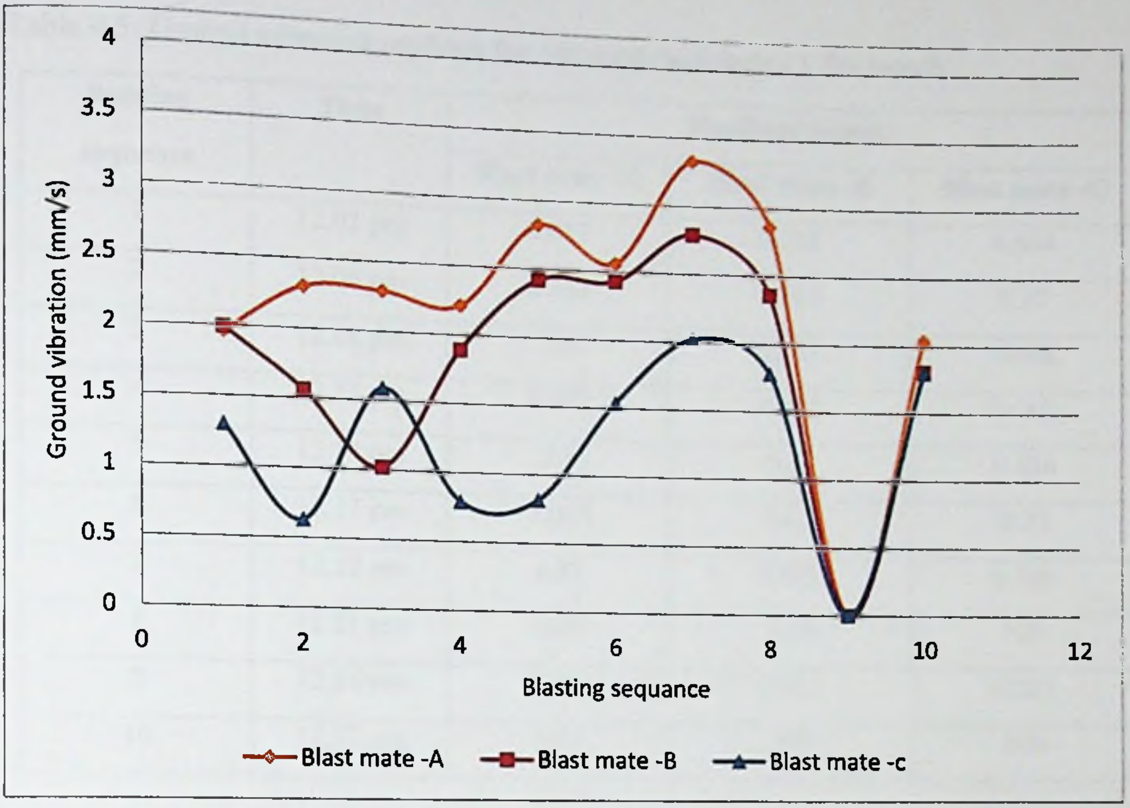

Figure 4. 5 : Ground vibration variation vs blasting sequence (2.5m bore holes,no trench)

Here,9th blasting was damaged due to 8th one,point B ground vibration less than point C at the 3rd blasting.

4.5 Bore hole depth 1m and trench 1.5m (set-5)

After constructed trench

Date	:2015/12/11	
Trench depth	:1.5 m	
Bore whole depth	:1 m	
No of holes	:10	
Explosive quantity per one hole	:01). Electric detonater	:150g :01
	(02). Water gel	:62.5g
	(03). ANFO	

Table 4.5: Ground vibration readings for 1m depth bore holes 1.5m trench

Blasting sequence	Time	Readings (mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	12.02 pm	0.617	0.218	0.804
2	12.06 pm	0.782	0.561	0.17
3	12.08 pm	1.06	0.357	0.498
4	12.11 pm	0.892	0.452	0.262
5	12.14 pm	2.4	0.24	0.456
6	12.17 pm	1.042	0.62	0.72
7	12.19 pm	0.88	0.421	0.346
8	12 21 pm	0.89	0.45	ND
9	12.24 pm	0.178	0.363	0.205
10	12.27 pm	ND	ND	ND

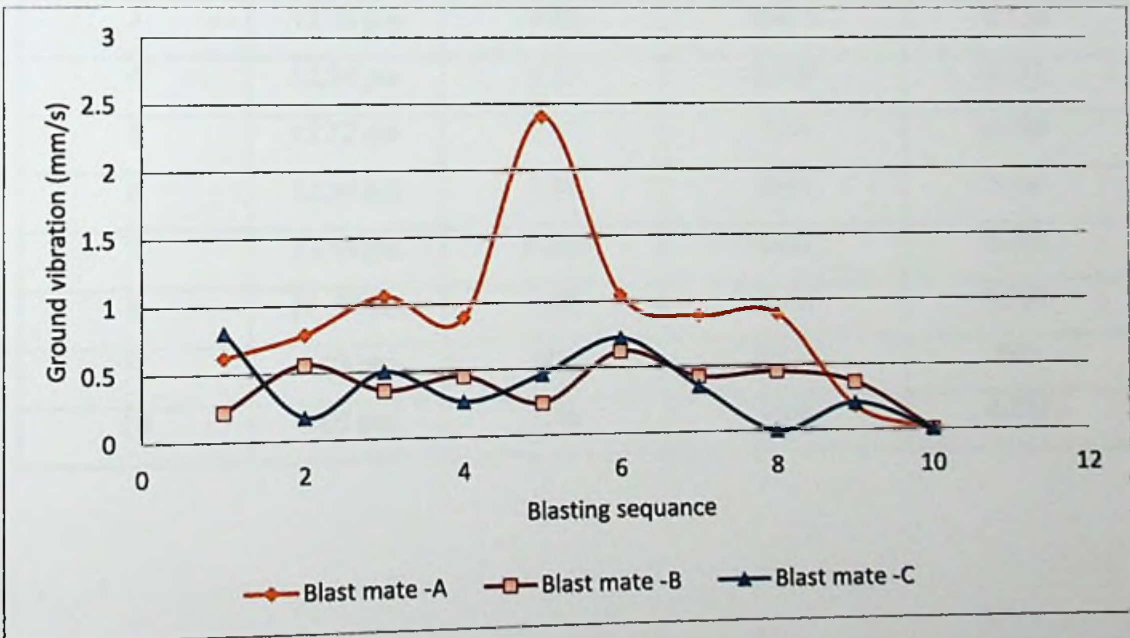

Figure 4.6 :Ground vibration variation vs blasting sequence (1m bore holes, trench depth 1.5m)

After constructing the trench,considerable ground vibration deference can be seen both side of the trench. Observation point, ground vibration value is higher than both side of the trench in the 1st blasting.

4.6 Bore hole depth 1.5m and trench depth 2m (set-6)

Date : 2015/12/11

Trench depth : 2 m

Bore whole depth :1.5 m

No of holes- 10

Explosive quantity per one hole : (01). Electric detonater :01

(02). Water gel :125g

(03). ANFO :300g

Table 4.6 : Ground vibration readings for 1.5m depth bore holes 2m trench

Blasting sequence	Time	Readings (mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	12.45 pm	0.269	0.166	0.285
2	12.47 pm	0.98	0.26	0.42
3	12.50 pm	0.08	0.413	0.124
4	12.51 pm	1.26	0.602	0.231
5	12.52 pm	2.67	1.34	0.489
6	12.54 pm	1.86	0.98	0.86
7	12.56 pm	0.479	0.221	0.702
8	12 .58 pm	1.22	0.66	0.321
9	1.03 pm	ND	0.135	ND
10	1.05 pm	1.56	0.54	0.222

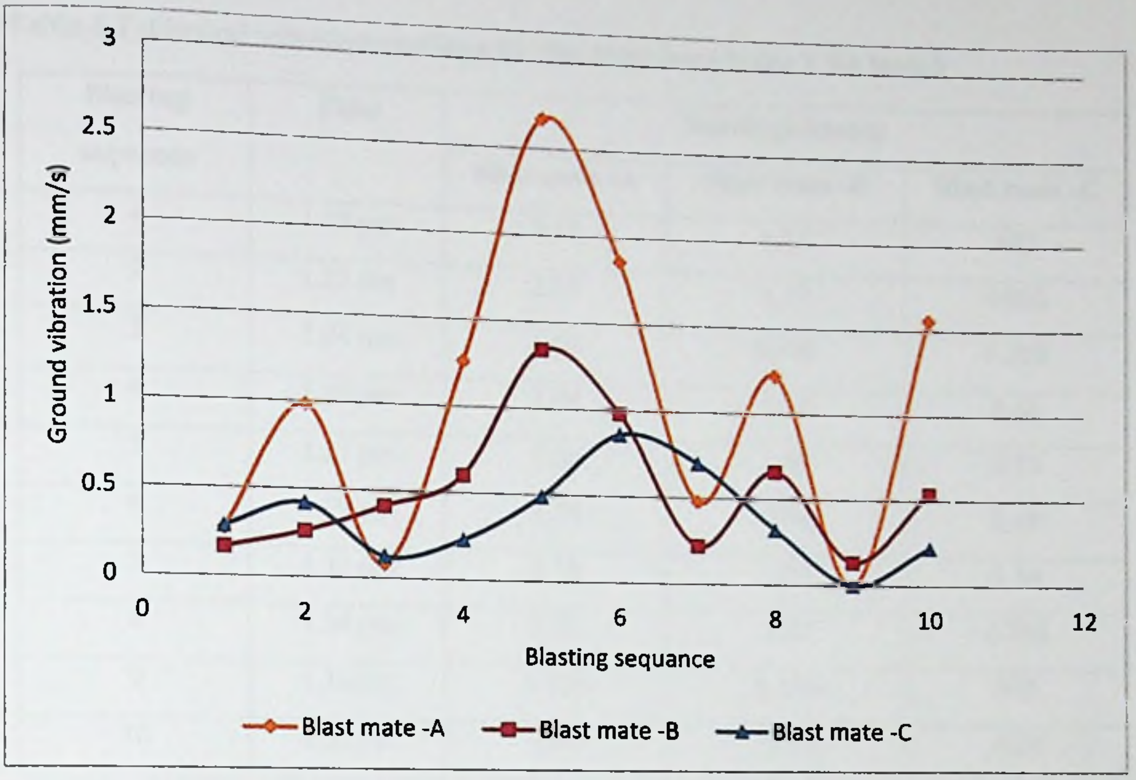

Figure 4.7 :Ground vibration variation vs blasting sequence (1m bore holes, trench depth 1.5m)

9th blasting was not detected at the point A and C, ground vibration value of observation point is higher than point A and B in the 7th blasting, which is over than point B value in 1st and 2nd blasting and over than point A value in the 3rd blasting.

4.7 Bore hole depth 2m and trench depth 2.5 (set-7)

Date	:2015/12/11	
Trench depth	:2.5 m	
Bore whole depth	:2 m	
No of holes	:10	
Explosive quantity per one hole	: (01). Electric detonater	:01
	(02). Water gel	:125g
	(03). ANFO	:634g

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Table 4.7 :Ground vibration readings for 2m depth bore holes 2.5m trench

Blasting sequence	Time	Readings (mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	1.20 pm	2.13	1.17	ND
2	1.22 pm	2.65	1.17	0.862
3	1.24 pm	1.32	0.889	0.308
4	1.25 pm	2.04	1.12	0.68
5	1.27 pm	1.06	1.09	0.13
6	1.29 pm	1.78	0.94	0.88
7	1.32 pm	1.19	1.03	1.34
8	1.34 pm	1.78	1.02	0.888
9	1.36 pm	0.619	0.256	ND
10	1.39 pm	0.98	0.56	0.28

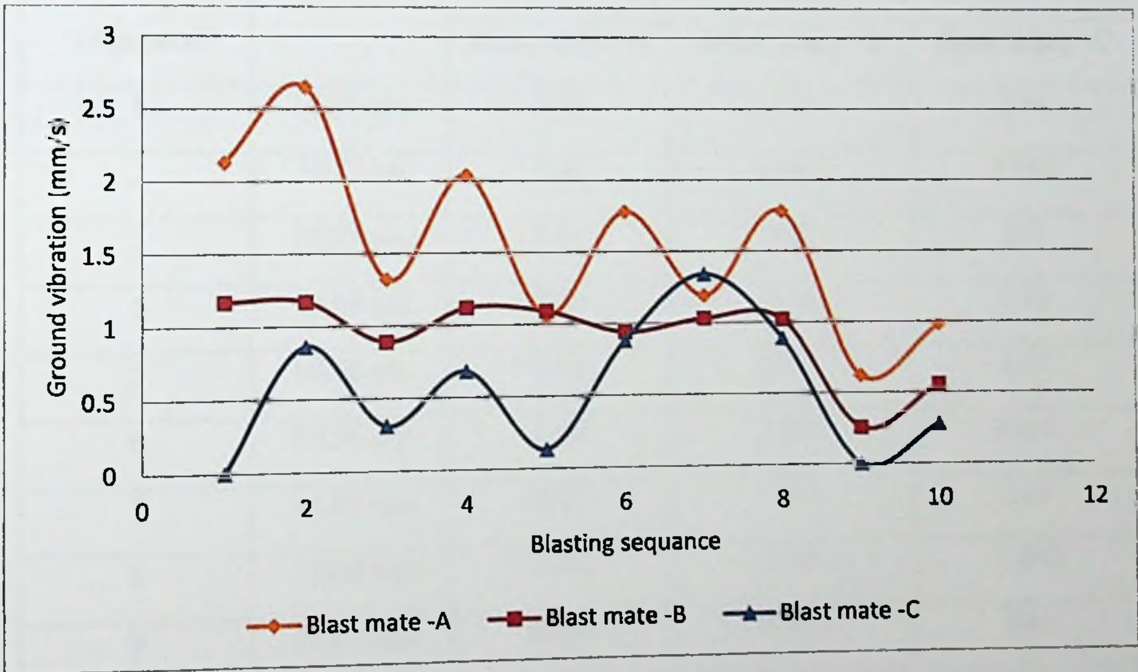


Figure 4.8 :Ground vibration variation vs blasting sequence (2m bore holes, trench depth 2.5)

1st and 9th blasting were not detected at the observation point.Considerable deference of ground vibration value can be seen among the both side of the trench and observation point except blast no 5,6 and 7 and ground vibration value of observation point is higher than point A and B in the 7th blasting.

4.8 bore hole depth 2.5m and trench depth 3m (set-8)

Date	:2015/12/12		
Trench depth	:3m		
Bore whole depth	:2.5 m		
No of holes	:10		
Explosive quantity per one hole	:(01). Electric detonater	:01	
	(02). Water gel	:125g	
	(03). ANFO	:850g	

Table 4.8 : Ground vibration readings for 2.5m depth bore holes 3m trench

Blasting sequence	Time	Readings (mm/s)		
		Blast mate -A	Blast mate -B	Blast mate -C
1	10.50 am	2.94	2.35	2.59
2	10.51am	2.46	1.662	0.882
3	10.53 am	3.31	2.18	2.3
4	10.54 am	2.56	1.46	1.22
5	10.56 am	3.02	2.77	2.12
6	10.58 am	2.88	1.022	0.902
7	11.01 am	4.22	3.02	2.18
8	11.04 am	3.44	2.46	1.802
9	11.07 am	0.668	0.309	ND
10	11.09 am	1.56	0.862	0.842

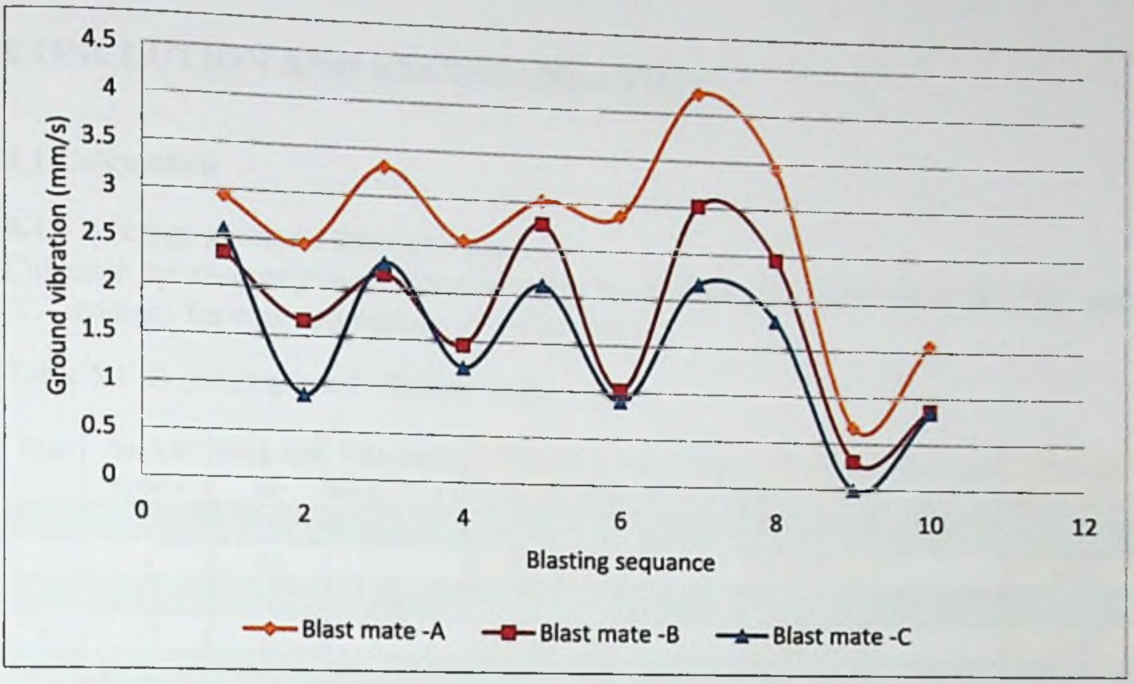


Figure 4.9 : Ground vibration variation vs blasting sequence (2.5m bore holes,trench depth 3m)

9th blasting was not detected at the observation point.considerable deference of ground vibration levels can be seen in between both side of the trench under these parameters (2.5m bore hole depth and 3m depth trench)

according to the all results of ground vibration variation show,considerable deference of vibration value can be seen both side of the trench, after digging.

CHAPTER 05

CONCLUTION AND RECOMANDATION

5.1 Calculation

5.1.1 Average ground vibration value

Calculate the average ground vibration value for each set (1 to 8) for point "A", "B", and "C" readings for easy comparison of trench effect.

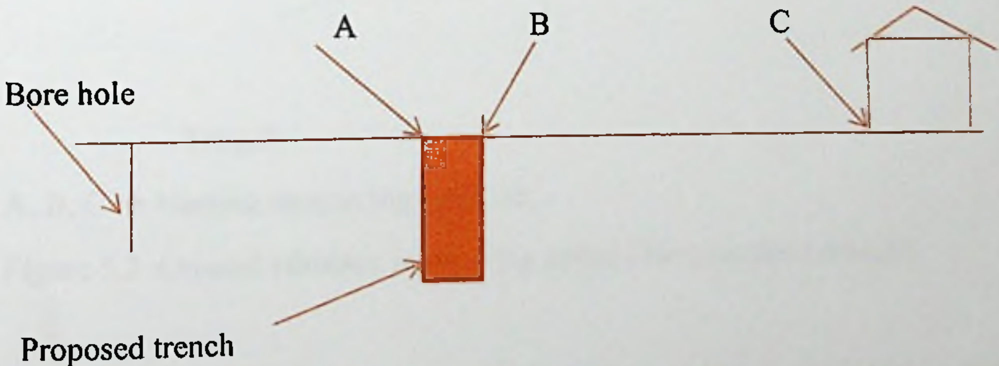
Table 5.1 :Average ground vibration value

Set no	Bore hole depth(m)	Trench depth (m)	Without trench average GV at A	With trench average GV at A	Without trench average GV at B	With trench average GV at B	Without trench average GV at C	With trench average GV at C
1	1	No	0.411		0.385		0.114	
5	1	1.5		0.971		0.409		0.432
2	1.5	No	0.894		0.883		0.407	
6	1.5	2		1.153		0.531		0.406
3	2	No	1.495		1.39		0.67	
7	2	2.5		1.555		0.925		0.671
4	2.5	no	2.485		2.03		1.362	
8	2.5	3		2.862		1.81		1.649

After taking average ground vibration value at the of point "A", "B" and "C", and compare these values without trench and with trench by calculating ground vibration reduction percentage at the point of "B" and "C" with point "A"

5.1.2 Ground vibration reduction percentage (Free trench blasting)(calculation-1)

Calculation of ground vibration reduction percentage of blast mate" B" and blast mate "C" with blast mate "A" at the trench proposed land.



A, B, C → blasting monitoring machine.

Figure 5. 1 :Ground vibration monitoring points (before construct trench)

GA-Average ground vibration at the point of A from 10 bore holes (Blast mate a readings)

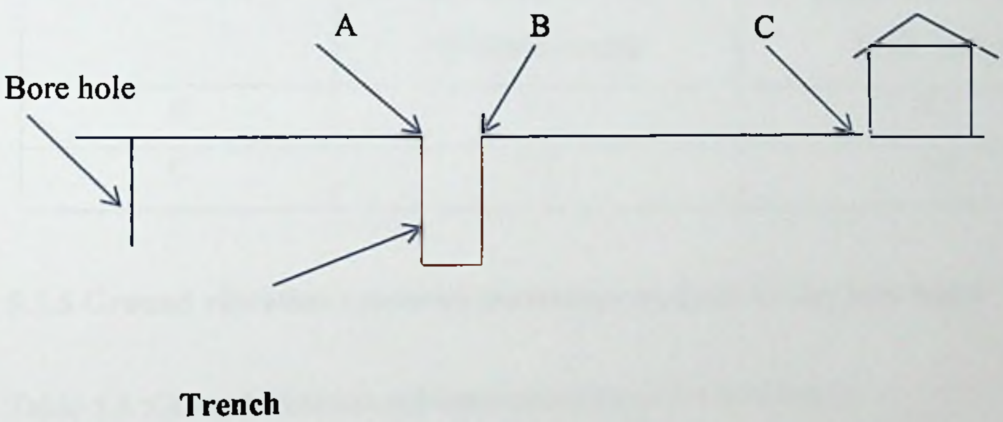
GB-Average ground vibration at the point of B from 10 bore holes (Blast mate B readings)

GC-Average ground vibration at the point of C from 10 bore holes (Blast mate C readings)

(V1)Ground vibration reduction % with A at the point of B = (GA-GB)/GA*100

(V2)Ground vibration reduction % with A at the point of C = (GA-GC)/GA*100

5.1.3 Ground vibration reduction percentage (Blasting with trench)(calculation -2)
Calculation of ground vibration reduction percentage of blast mate "B" and blast mate "C" with blast mate "A" at the trench constructed land.



A, B, C → blasting monitoring machine.

Figure 5.2 :Ground vibration monitoring points (after construct trench)

GA-Average ground vibration at the point of A from 10 bore holes (Blast mate "A" readings)

GB-Average ground vibration at the point of B from 10 bore holes (Blast mate "B" readings)

GC-Average ground vibration at the point of C from 10 bore holes (Blast mate "C" readings)

(V3)Ground vibration reduction % with A at the point of B = (GA-GB)/GA*100

(V4)Ground vibration reduction % with A at the point of C = (GA-GC)/GA*100

5.1.4 Comparison of Ground vibration reduction percentage

Calculation-01 and calculation-02 are done for same bore whole depth and compare V1 with V3 and V2 with V4.

Table 5.2 : Ground vibration reduction percentage

Blast mate no	GV Reduction % with " A" Without trench	GV Reduction % with "A" With trench
B	V1	V3
C	V2	V4

5.1.5 Ground vibration reduction percentage analysis for 1m bore holes

Table 5.3 :Ground vibration reduction percentage (1m bore holes).

Blast mate no	GV Reduction % with " A" Without trench	GV Reduction % with "A" With 1.5m trench
B	6.326	57.878
C	72.262	55.509

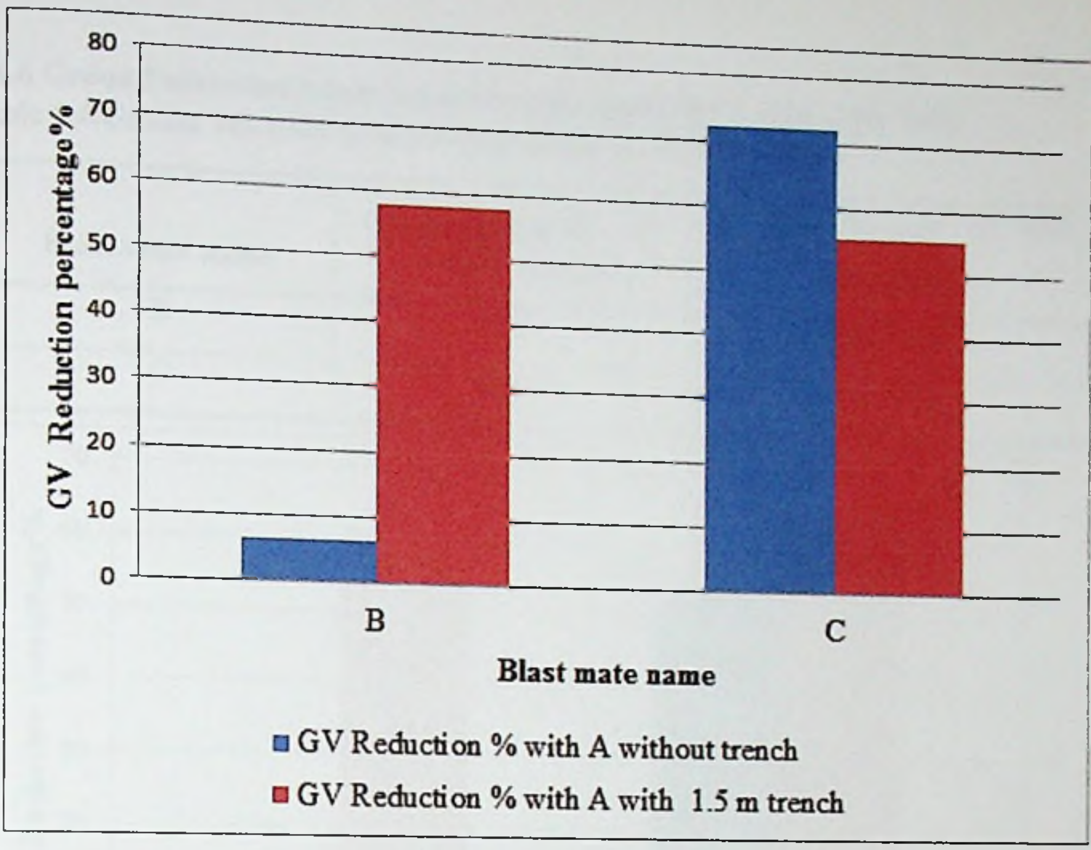


Figure 5.3 : Comparison of GV reduction % (1m bore holes)

According to the above column chart, ground vibration reduction percentage can be explained clearly for 1 m depth bore holes. Point "B" and point "C" reduction percentage calculated with point "A", when compare the distance to "B" and "C" from "A" ,distance "A" "B" is nearly to trench width (1.3 m) which is very shorter than the distance "A" "C" (39 m).witching very short distance at the "B" ground vibration reduction percentage is very high with trench which is 57.87% but same location without trench which is 6.33%

When consider point "C" ground vibration reduction percentage with "A", which are 72.26% without trench and 55.51% with trench.

5.1.6 Ground vibration reduction percentage analysis for 1.5m bore holes

Table 5.4:Ground vibration reduction percentage (1.5m bore holes).

Blast mate name	GV Reduction % " A" without trench	GV Reduction % "A" with 2 m trench
B	1.23	53.946
C	54.474	64.787

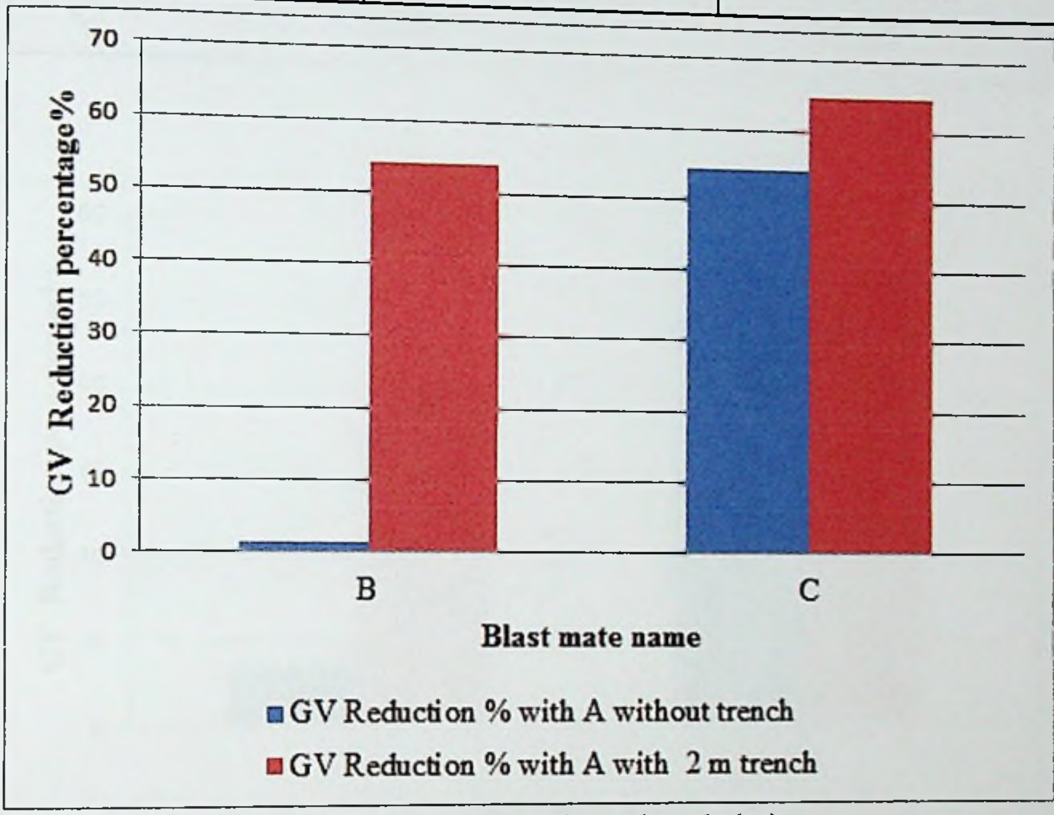


Figure 5.4 Comparison of GV reduction % (1.5m bore holes)

According to the above column chart, ground vibration reduction percentage can be explained clearly for 1.5 m depth bore holes. Point "B" and point "C" reduction percentage calculated with point "A", when compare the distance to "B" and "C" from "A" ,distance "A" "B" is nearly to trench width (1.3 m) which is very shorter than the distance "A" "C" (39 m).witching very short distance at the "B" ground vibration reduction percentage is very high with trench which is 53.95% but same location without trench which is 1.23%

When consider point "C" ground vibration reduction percentage with "A", which are 54.47% without trench and 64.79% with trench.

5.1.7 Ground vibration reduction percentage analysis for 2m bore holes

Table 5.5 :Ground vibration reduction percentage (2m bore holes).

Blast mate name	GV Reduction % with A without trench	GV Reduction % with A with 2.5 m trench
B	7.023	40.514
C	55.183	56.848

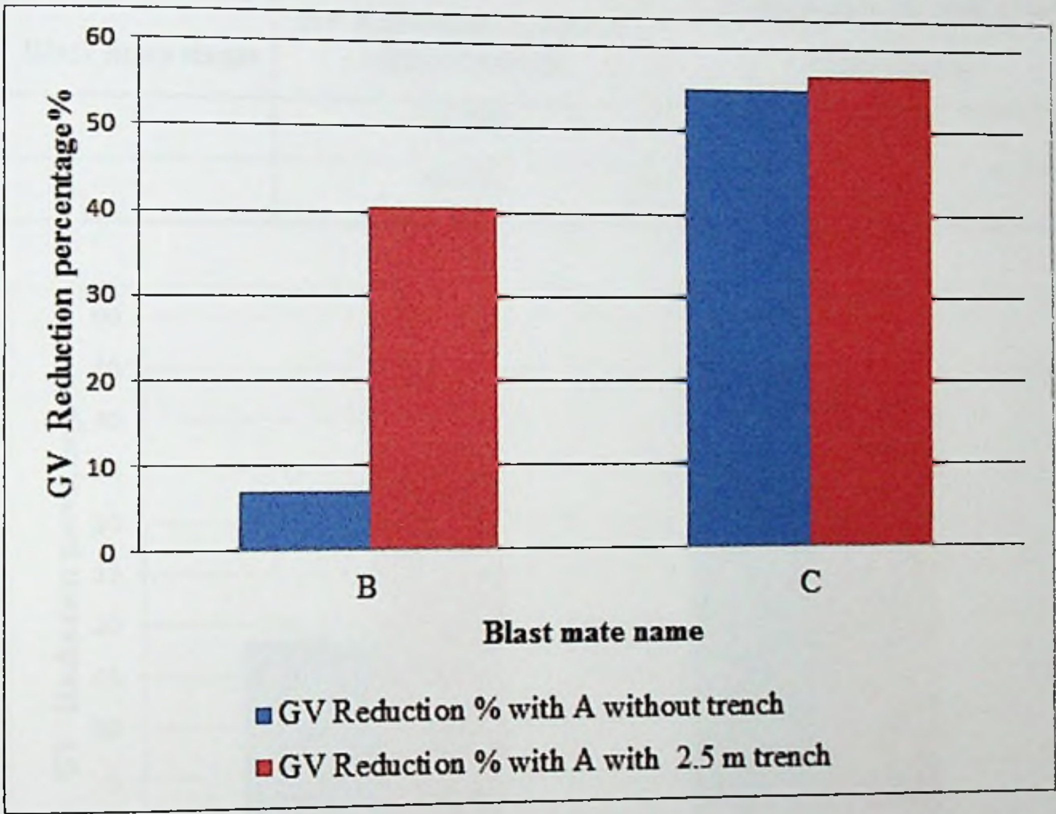


Figure 5.5 :Comparison of GV reduction % (2m bore holes)

According to the above column chart, ground vibration reduction percentage can be explained clearly for 2.0 m depth bore holes. Point "B" and point "C" reduction percentage calculated with point "A", when compare the distance to "B" and "C" from "A" ,distance "A" "B" is nearly to trench width (1.3 m) which is very shorter than the distance "A" "C"

(39 m).witching very short distance at the "B" ground vibration reduction percentage is very high with trench which is 40.51% but same location without trench which is 7.02%

When consider point "C" ground vibration reduction percentage with "A", which are 55.18% without trench and 56.85% with trench.

5.1.8 Ground vibration reduction percentage analysis for 2.5m bore holes

Table 5.6 :Ground vibration reduction percentage (2.5m bore holes).

Blast mate name	GV Reduction % with A without trench	GV Reduction % with A with 3.0 m trench
B	18.309	36.758
C	45.191	42.382

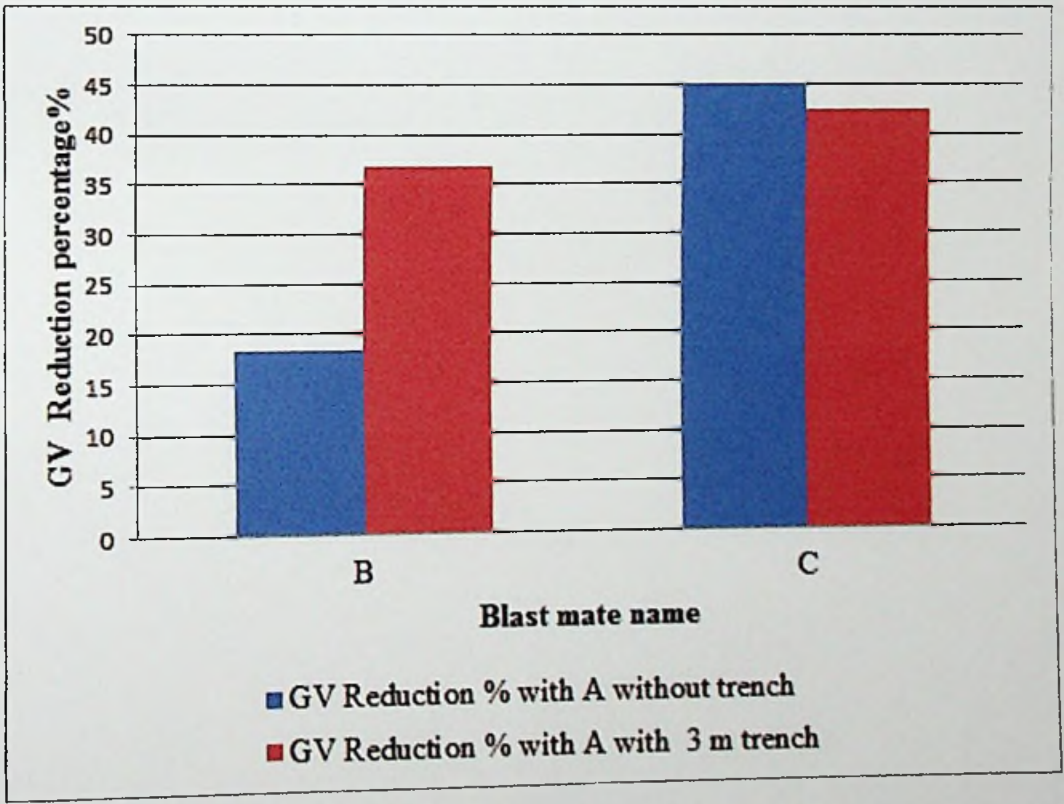


Figure 5.6 :Comparison of GV reduction % (2.5m bore holes)

According to the above column chart, ground vibration reduction percentage can be explained clearly for 2.5 m depth bore holes. Point "B" and point "C" reduction percentage calculated with point "A", when compare the distance to "B" and "C" from "A" ,distance "A" "B" is nearly to trench width (1.3 m) which is very shorter than the distance "A" "C" (39 m).witching very short distance at the "B" ground vibration reduction percentage is very high with trench which is 36.75% but same location without trench which is 18.30%

When consider point "C" ground vibration reduction percentage with "A", which are 45.19% without trench and 42.38% with trench.

5.2 Conclusion and recommendation

Trenches can be used as a ground vibration reduction system in the quarry industry, because summarized results for all trench depth indicate ground vibration reduction percentages are very high immediately after the dug trench(active isolation system).
However considerable deferences of reduction levels have not been observed at the observation point and therefore passive isolation system can not be applied in this situation

Arranging trench in areas such as the observation point as located in this study where necessary to reduce the ground vibration, could be helpful to achieve the best results. Applying of this method to Sri Lankan quarry industry could reduce many problems faced by the quarry owners regarding vibration damages and run such quarries profitably.

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ANNEXURE

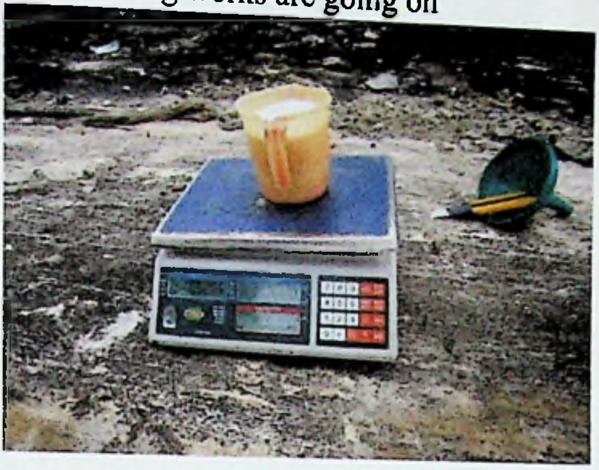
Annex – 1

Location of the work site

Annex – 2

Work site photos

Test blasting works are going on



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