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GUIDELINES FOR INDUSTRIAL ROCK BLASTING

Dr. H. S. Welideniya
Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka.
senaka@earth.mrt.ac.lk

Abstract

Under all circumstances "Industrial Blasting" needs to be carried out without inflicting disastrous affects on the neighbourhood. If it is carried out considering engineering properties of rock mass being blasted and with the proper quantification of blastability of explosives blasting can be done without inflicting any adverse affects caused by ground vibrations, ecological damage and also maintaining air blast overpressure below human tolerance levels. It is widely recognized that two aspects such as structural damage and human response are the ones which merit particular attention in surface mine and construction blasting. Under such circumstances blasting has to be carried out in a well designed manner. The affect of engineering geological properties of rock mass in blast designs and the role of quarry factor in blasting are discussed in this paper. The paper also describes the importance of the establishment of site constants for quarries. These factors will facilitate the design of better bench blast geometries, determination of maximum instantaneous charge for required ground vibration which will affect least environmental damage/noise control thus leading to better blasting practices.

1. Introduction

Industrial Rock Blasting in quarries and road cuts need to be designed properly to avoid any structural damage it might cause to existing civil structures, construction works and the environment. This requires establishment of properties of the rock mass being fragmented and the knowledge of explosive strength being used in blasting. It will be necessary to find a delicate balance between environment and blasting by inventing guidelines for their peaceful co-existence. Therefore if blasting is done where construction works are in progress or in populated areas, it need to follow certain guidelines to minimize the potential risk to the environment.

2. Blasting

Mining of construction materials and minerals are associated with blasting. In addition road construction work also uses blasting in the excavation of road cuts. The use of explosives for extraction work and road cut excavation is an efficient method where low labour requirements needed to be matched with skilled labour able to handle explosives. However, the environmental impact of explosive usage cannot be totally neglected.

The use of explosives and blasting is generally seen with the following activities:

a) Underground mining
b) Open-pit mining and quarrying
c) Road cuts
d) Hazard prevention (to remove large boulders, to stabilize slopes, etc.)

The Industrial Explosives and Blasting Agents used in Sri Lanka in all types of blasting activities are:

a) Gelignite or Dynamite
b) ANFO
c) Emulsions

The blasting methods used are as follows:

a) Electric blasting.
b) Blasting with safety fuse and plane detonators.
c) Blasting by detonating cord.
d) Nonel blasting.

3. Types of blast waves and their propagation

The main wave types generated in a blast are as follows:

- Compressional waves (*P*)
- Rayleigh waves (*R*)
- Shear Waves (*S*)
- Love waves (*L*)

It was noted that in dense brittle rigid medium ground motion is less than in unconsolidated medium. However in dense brittle rigid medium frequency is higher for all events. *P* wave is less attenuated in rigid dense media.

4. Problems associated with present practices

4.1Mining and other underground excavations:

The excavation activities carried out underground could cause numerous complications on the ground surface if they are not being handled with proper engineering knowledge. The widely seen problems arising from underground mining/excavations that have a direct impact on civil construction works on the surface are as follows:

a) Subsidence
b) Change of the ground water table
c) Ground settlement

4.2 Surface Mining

Surface Mining is the one, which attracts maximum attention due to its adverse environmental impact. Widely seen problems that are associated with the surface mining are as follows:

a) Destruction of the natural landscapes
b) Slope failure
c) Erosion
d) Dust
e) Creation of water accumulated ponds (or lakes in large-scale open pit mining)

Slope failure is the main factor, which could threaten civil construction works if such activities are carried out close to the outer boundary of the Quarry or the Open-pit. But most of the problems caused on construction works by surface mining can be directly attributed to blasting works.

5. Blasting

5.1 Blasting underground

Underground blast vibrations at depth, is generally not felt on the surface. Blasting underground does not cause any serious threat to surface construction works.

5.2 Blasting on the surface

Surface blasting has always being the most problematic area whose operations are very often challenged by the local population. Improper and unprofessional execution of blasting works in quarries is the main factor which invites problems thus hampering the production works of such quarries. The detrimental impacts caused civil construction practices are as follows:

a) Ground vibration
b) Fly rocks
c) Air blast

The following directly reflects the above said affects:

a) Ground vibration-Cracking of walls (Figure 1)
b) Fly rocks - Injuries (sometimes fatal)
c) Air blast - Shattering of glasses, structural damage and unpleasantness.

6. Mitigatory measures

The adoption of proper mitigatory methods in areas where mining and blasting works are carried out will minimize their adverse effects on existing civil structures as well as on ongoing construction works whilst maintaining a delicate balance among these activities.

a) Measurement of peak particle velocity (mm/s) resulting from test blasts at nearby houses (Figure 2), critical locations and points of interest and maintenance of peak particle velocity below the threshold limits (as given in Table 1). Then redesign the blast geometry to comply with PPV recommended by standards.

b) When any concreting works are done carrying out them in complement with the Table 2 or by temporary interruption of blasting works until the age of the concrete reaches the permissible level.

c) Use of the correct borehole geometry for the blast (Figure 2)

i) Burden (B):

Less the burden greater the fragmentation and fly rocks Greater the burden lesser the fragmentation and fly rocks but greater the ground vibration. Correct choice of burden depends on rock engineering properties (specific gravity, strength, joints, etc.), bulk strength of the explosive used, borehole diameter.

General values for burden 1m to 2m

ii) Depth of bore-hole (L):

Depends on the capacity of the equipment available (drilling scaling loading), designed bench height and anticipated production. Generally 3m for 32mm diameter bore hole and 6m for 65mm diameter bore holes.

iii) Spacing between bore holes in the same line and spacing between rows:

Greater the distances greater the ground vibrations and lesser the

Line	Types of structures	Vibration velocity Foundation at a frequency of less than 10 HZ	10 to 50 HZ	50 to 100* HZ
1	Buildings used for commercial purposes. Industrial buildings and buildings of similar design	20	20 to 40	40 to 50
2	Dwellings and buildings of similar design and / or use	5	5 to 15	15 to 20
3	Structures that , because of their particular sensitivity to vibration , do not correspond to those listed in lines 1 and 2 and of great intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 6	8 to 10

**For frequencies above 100 HZ, at least the values specified in this column shall be applied*

Table 1: Vibration Effects on structures (DIN 4150 Part 3)

fragmentation and fly rocks. Lesser the distances lesser the ground vibration and greater the fragmentation. Correct choice of spacing depends on rock engineering properties (strength, joints, etc.), type of explosive, amount of delays used and borehole diameter.

General values for spacing

- Spacing between holes in the same row 1.25m to 1.5m and spacing between rows 1m to 1.75m (for bore holes of 32mm diameter)

Concrete age	Permissible PPV mm/sec
0 – 4 hours	limit No
4 – 24 hours	No blasting allowed
24 hrs – 3 days	10 mm/sec
2 – 3 days	25 mm/sec
3 – 7 days	35 mm/sec
After 07 days	50 mm/sec

Table 2: Vibration threshold limits for concrete during curing stage (at temperatures above 21 degrees centigrade)

- Spacing between holes in the same row 2.0m to 2.5m and spacing between rows 1m to 1.75m (for bore holes of 65mm diameter)

Strongly depend on rock eng. properties, bore hole diameter and the type of explosive.

iv) Bore hole diameter

For competent strong rock larger diameter (depending also on the required production) bore holes can be recommended (65 mm) For rocks with a higher density of joints smaller diameter bore holes (32mm)

v) Stemming

Good stemming controls air blast and fly rocks. Stemming should be competent to prevent the release of gases generated by the explosion through the collar of the borehole.

Stemming height (generally) = 0.7 * burden

Doubling or trebling the stemming height to prevent adverse effects resulting from a badly designed blast will not offer any acceptable solution to counter them.

vi) Sub-drilling

Depends on the Eng. properties of the rock mass and the burden.

Approx. value for Sub drilling = 0.3 * Burden

vii) Angle of inclination of the borehole

Depends on the designed bench angle which is the result of the consideration of all factors concerning the rock mass stability.

Generally from 70^0 to 90^0

The use of correct blast design will avoid the unpleasant consequences resulting from rock blasting (Figure 3). The following table (Table 3) can be used as a final guideline which includes all the factors discussed for trouble free execution of blasting work which will not have any negative effect on civil construction.

Stiffness Ratio L/B	1	2	3	4
Fragmentation	**Poor**	**Fair**	**Good**	**Excellent**
Air blast	**Severe**	**Fair**	**Good**	**Excellent**
Fly rock	**Severe**	**Fair**	**Good**	**Excellent**
Ground vibration	**Severe**	**Fair**	**Good**	**Excellent**
Remarks	**Redesign the blast**	**If any houses are located close by redesign the blast geometry**	**Safe to execute the blast**	**Safe to execute the blast, but do not increase the stiffness ratio beyond 4**

Table 3: "Rules – of Thumb" for blast geometry design

7. Conclusions

The use of correct blast geometry and explosives will facilitate rock blasting in any urban area. The adverse effects of blasting is controllable to a greater extent if proper emphasize is paid to all the aspects of blast design including the choice of bore hole diameter. However, the use of well established "rules-of-thumb" of blasting practices in blast designing could be effectively used to minimize adverse environmental impacts caused by rock blasting.

8. References

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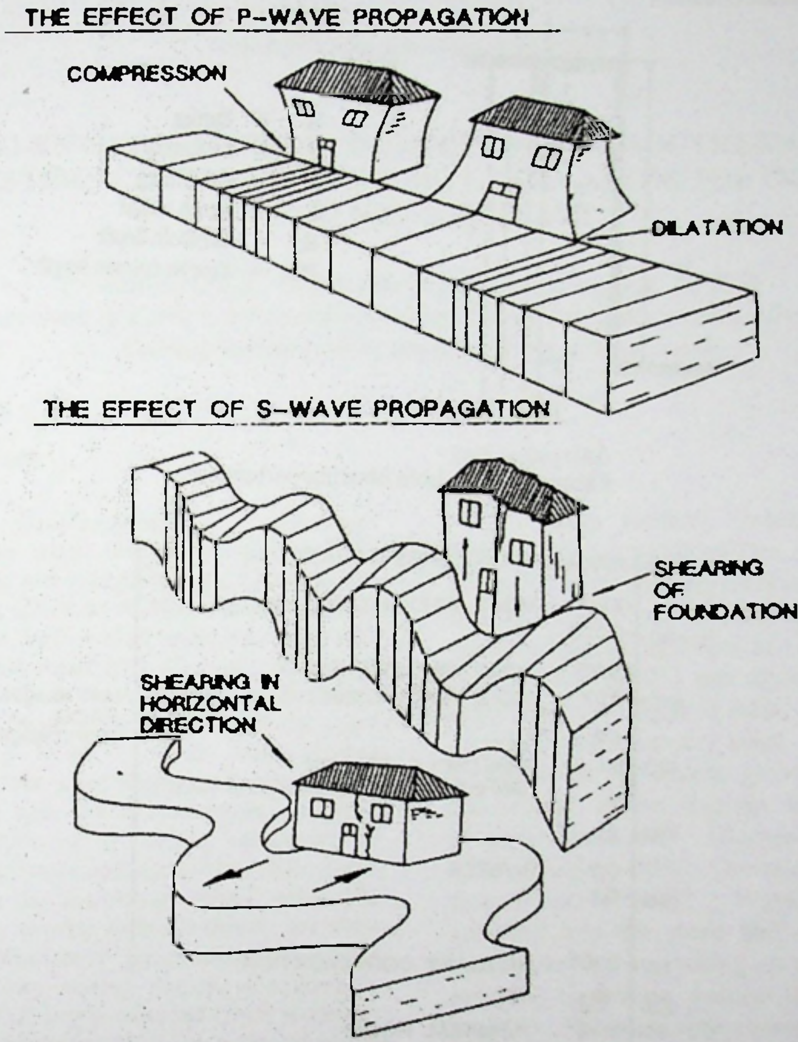
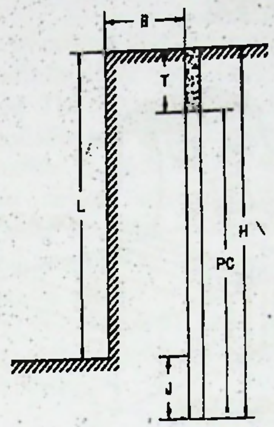


Figure 1: Effects of P and S waves on structural damage



where:

B	=	Burden
T	=	Stemming
J	=	Subdrilling
L	=	Bench height
H	=	Blasthole depth
PC	=	Powder column length

Figure 2: Bore-hole blasting parameters

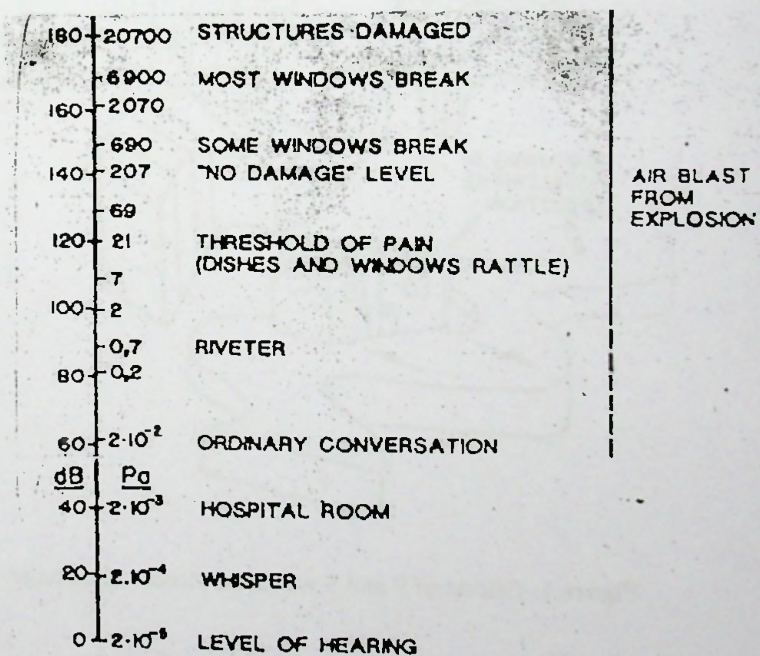


Figure 3: Human and structural response to sound pressure levels