208 Rock Blasting

General Information

This section only covers the basic concepts of rock blasting. The topic is covered in more detail in the FHWA manual *Rock Blasting and Overbreak Control*, FHWA-HI-92-001. Many of the figures and specification concepts originated from this manual. The manual is available on the FHWA website:

www.fhwa.dot.gov/engineering/geotech/library_listing.cfm

There used to be a training course from NHI for Rock Blasting and Overbreak Control, but unfortunately this course is no longer available from NHI.

Rock Blasting Basics

Rock blasting consists of drilling holes in the rock at depths, in diameters, and at spacing so that the ANFO (which is a mixture of Ammonium Nitrate [fertilizer] and Fuel Oil [diesel fuel]) can fracture the rock in a controlled manner. The rock must fracture enough to displace it and break it down to the size of the intended use.

The specifications limit the way blasting contractors can blast so that rock or blast vibrations do not harm people or adjacent property.

Blasting Free Body Diagram

The basic geometry for rock blasting is shown in Figure 208.A.

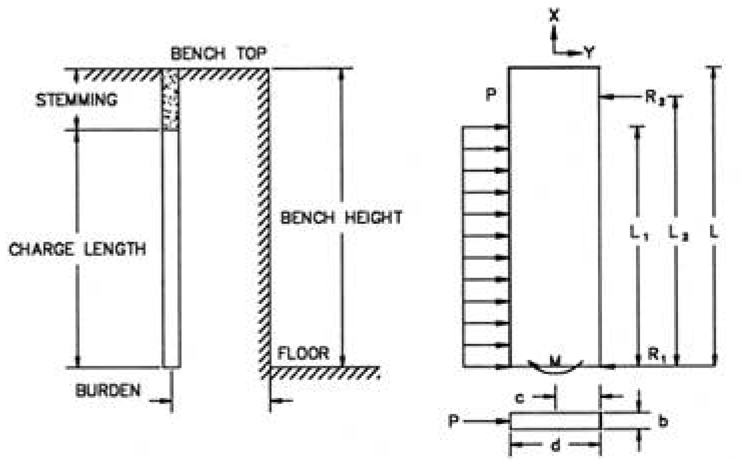


Figure 208.A – Rock Blasting Free Body Diagram

Holes are drilled to the required depth to remove the rock, and filled with ANFO (the charge length). The charge is topped off with stemming that helps hold the blast down. The free body diagram in the right-hand side of Figure 208.A shows the explosive pressure P and moment M from the blast.

The blaster and blasting consultant can arrange the geometry of the blast for optimal breakage. This is done so that P and M do not exceed the amount needed to break the rock. Excessive P and M causes flyrock and excessive air blast and vibrations that can cause damage and injury.

Blasting Geometry and Symbols

Figure 208.B further defines the rock blasting geometry.

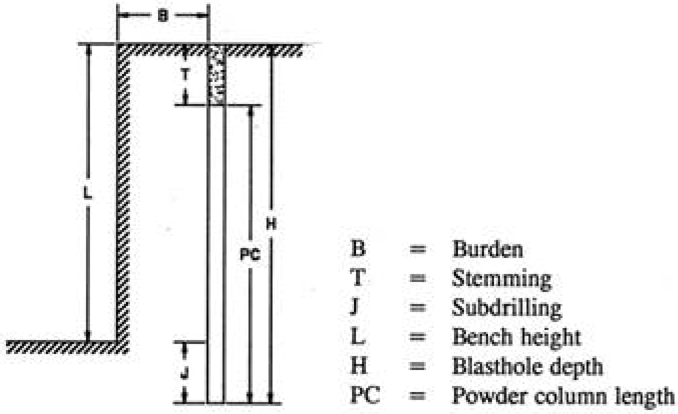


Figure 208.B – Rock Blasting Geometry and Symbols

Figure 208.B illustrates the following blast geometry parameters:

- B (Burden) is the distance between the free face and the first hole.
- T is the stemming (the inert material in the hole).
- L is the length of the bench height.
- H is the hole depth.
- PC is the Powder Column Length. (ANFO).
- J is the subdrill depth or the depth the hole extends below the planned cut.

Two main parameters to remember here are the L/B ratio and the stemming height.

Hole Spacing and Timing

The top view of the rock blasting geometry is shown in Figure 208.C. Notice the distance B is still the distance to the free face. The distance, S, or spacing of the holes is a function of the burden.

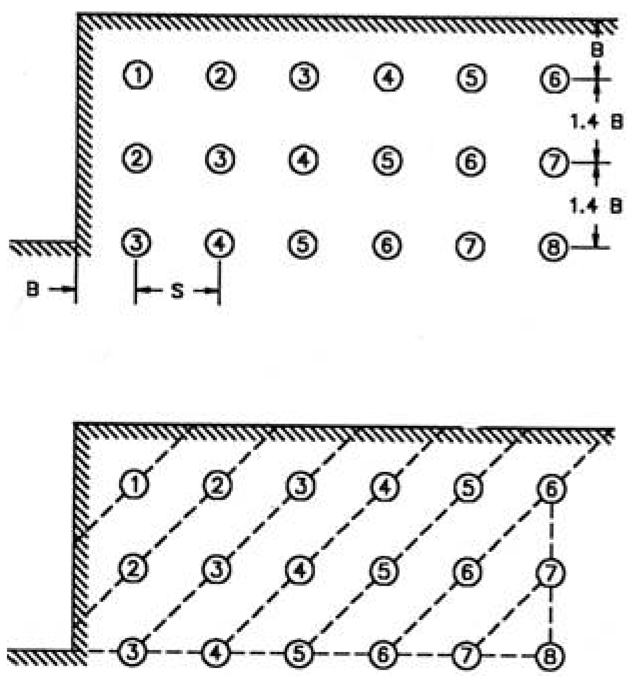


Figure 208.C – Rock Blasting (top view)

The spacing of the holes and the timing (or delay) of the holes are part of the blasting design. The bottom illustration in Figure 208.C shows how the blast is delayed by the sequencing numbers. Each hole may be blasted milliseconds apart to control the blast. The row-to-row shots are certainly time delayed.

An initiation system transfers the detonation signal from hole to hole at precise times. Plastic shock tubes or electric caps using a timing system are generally employed. A shock tube is non-electric, instantaneous, and has a thin reactive powder that propagates the shock wave signal.

The timing or delay minimizes the pounds of explosive per delay period. This can significantly control noise and vibration effects. It would be a disaster if all the holes went off at the same time.

The design variables of burden, stemming, subdrill length, spacing, and timing are selected to maximize fragmentation and to minimize excessive vibration, air blast, and flyrock.

Effects of L/B Ratio

Figure 208.D shows what happens when the ratio between the distance L (Bench Height) and the Burden (B) is changed. Potential blasting problems are decreased as the ratio is increased. As this ratio is decreased, these problems are increased.

Stiffness Ratio (L/B)	1	2	3	4
Fragmentation	Poor	Fair	Good	Excellent
Air Blast	Severe	Fair	Good	Excellent
Flyrock	Severe	Fair	Good	Excellent
Ground Vibration	Severe	Fair	Good	Excellent
Comments	Severe backbreak & toe problems. Do not shoot. REDESIGN!	Redesign if possible.	Good control and fragmentation	No increased benefit by increasing stiffness ratio above 4.

Figure 208.D – Potential Problems as it Relates to Stiffness Ratio L/B

The specifications in 208.06.C require this ratio to be greater than one. ODOT blasters design the correct timing, hole spacing and stemming, and have not had problems with designs having a L/B ratio near one. Local blasters are also very familiar with local geology.

Generally, a ratio near one maximizes the rock blasting production. The main problem with designing a ratio that is near one is that the rock generally fractures in large chunks. This can pose problems for the Contractors when trying to use the material for fill.

When the ratio is increased, it can decrease the particle size of the rock. This allows the material to be used as fill easier.

Proper Burden

In order to ensure that the blaster is using the proper burden, follow this rule of thumb: the burden is usually 24 to 30 times the production hole diameter. For example:

If the production holes have a diameter of 6 inches (0.5 feet) then the burden should be:

$$24 \times 0.5 \text{ ft} = 12 \text{ ft} \quad \text{or} \quad 30 \times 0.5 \text{ ft} = 15 \text{ ft}$$

The burden for the shot should be between 12 and 15 feet.

Effects of Stemming

The specifications in 208.06.E require that the stemming depth (T) of inert material be at least 0.7 times the burden (B). This helps control the air blast.

Figure 208.E depicts the effects of stemming. If effective, the blast direction is lateral. If the stemming is ineffective, the blast can blow upward and cause excessive air blast. Notice that in the example, the blast cuts back into the cut slope. This is an obvious problem.

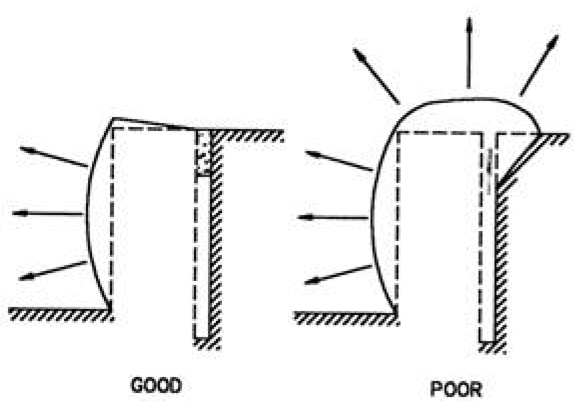


Figure 208.E – Stemming Effects

Drill cuttings are normally used for stemming. However, when blasting in water-filled production holes, or when blasting within 200 feet of a structure, the stemming material is changed to prevent problems. For holes less than 4 inches in diameter, crushed No. 8 stone is required. For holes 4 inches in diameter or larger, No. 57 stone is required. This helps hold the blast down better.

Effects of Timing

Timing the blast is another important parameter. Figure 208.F depicts the effects of poor and good timing.

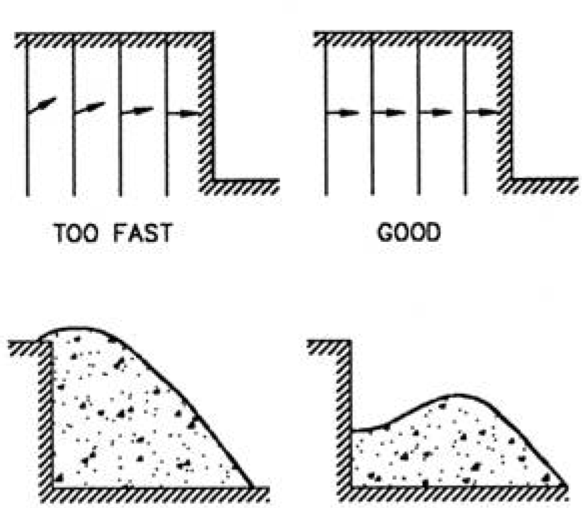


Figure 208.F – Timing Effects

With correct timing, the blast has a distinct lateral movement. With poor timing, the movement is more upright and has potential problems.

Vibration and Air Blast Monitoring

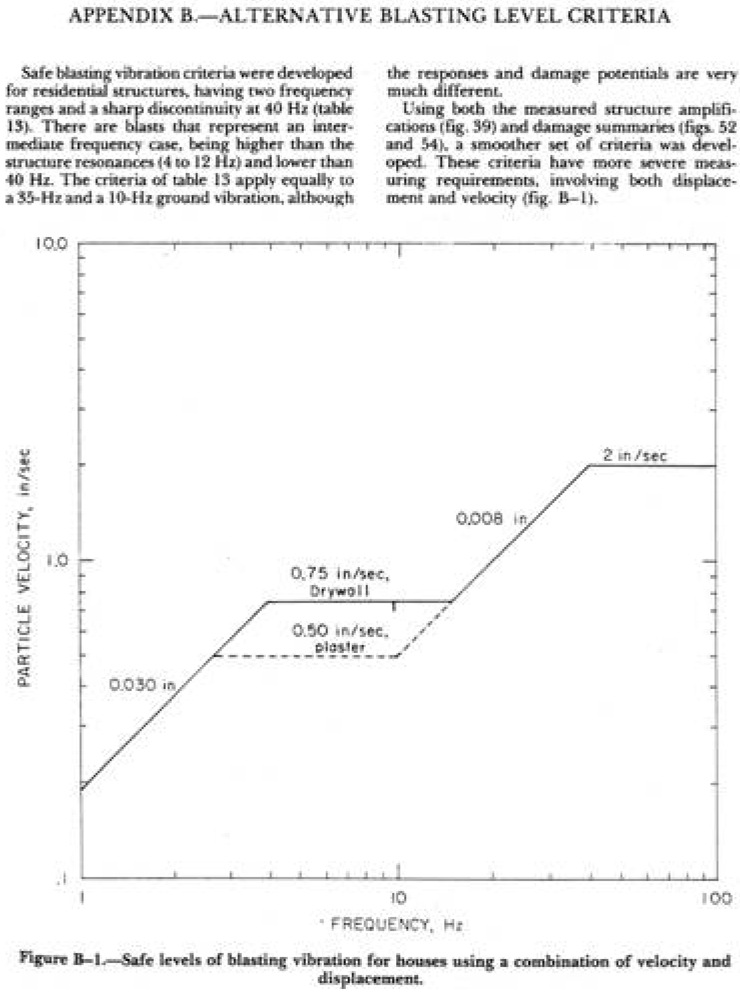
The blaster is required to design the burden, stemming, subdrill length, spacing, and timing to minimize excessive vibration, air blast, and flyrock. The blaster must monitor the air blast and vibration for every shot at the nearest structure. Seismographs are used to monitor the vibration.

Specialized equipment is used to monitor the air blast. The maximum air blast, in 208.16.A, is required to be under 134 dB. The air blast limit may need to be lower to prevent damage.

A typical vibration criterion is given in Figure 208.G. This is from the US Bureau of Mines.

To lower the air blast, check the stemming height and type of material used for the stemming. Thin or thick areas of the burden may create excess air blast and even flyrock. Measure the burden to the free face to ensure a uniform burden.

To lower the vibration everything needs to be checked. This includes the blast design and layout of the blast holes.


APPENDIX B.—ALTERNATIVE BLASTING LEVEL CRITERIA

Safe blasting vibration criteria were developed for residential structures, having two frequency ranges and a sharp discontinuity at 40 Hz (table 13). There are blasts that represent an intermediate frequency case, being higher than the structure resonances (4 to 12 Hz) and lower than 40 Hz. The criteria of table 13 apply equally to a 35-Hz and a 10-Hz ground vibration, although the responses and damage potentials are very much different.

Using both the measured structure amplifications (fig. 39) and damage summaries (figs. 52 and 54), a smoother set of criteria was developed. These criteria have more severe measuring requirements, involving both displacement and velocity (fig. B–1).

Figure B–1.—Safe levels of blasting vibration for houses using a combination of velocity and displacement.

Figure 208.G – Typical Vibration Blasting Criteria

Each blast has a particle velocity and frequency. The project can plot these values on the chart in Figure 208.G. If the point is lower than the plotted line, then the blast is within limits that are considered to be safe.

Presplitting (208.09)

Presplitting is a very effective method of controlling the final appearance of steep slopes; it can result in a clean sheared face. Presplitting is required when the slope is steeper than 1H:1V and deeper than 5 feet.

Specialized presplit blasting explosives are used. Hole diameters are about 3 inches, and the presplit holes are blasted prior to the production blast. The presplit hole spacing is started at 36 inches. This is adjusted to obtain a good shear face of the rock.

Documentation Requirements - 208 Rock Blasting

1. Accept preblast survey.
2. Verify the experience of the Blasting Specialists.
3. Accept and verify the blasting plan.
4. Ensure that the Item CA-EW-10 Item 208 Blasting Drilling Log is prepared by the Driller.
5. Review the blasting area for blasting plan dimensions with the blasting consultant.
6. Control Blasting is used on cut slopes steeper than 1:1 and deeper than 5 feet (1.5 m). Techniques are outlined in Section 208.10.
7. Production blasting is for widely spaced production holes in the main excavation
8. Review the regulations of explosives as outlined in Section 107.09
9. Blasting plan is required at least 2 weeks before drilling begins.
10. Review the detailed blasting plan of test shots.
11. Document test sections and drilling patterns.
12. Document safety procedures as outlined in 208.08. Ensure that the CA-EW-11 Item 208 Rock Blasting Site Security Plan is prepared by the Blaster.
13. Witness all shots. Inspect all shots using the CA-EW-9 Item 208 Rock Blasting Field Inspection Form.
14. Check vibration, air blast and flyrock for all blasts.
15. Check monitoring wells with Hydrologist.

16. Check the presplit face and requirements.
17. Measure presplit areas.
18. Monitor blasting consultants' hours.
19. Review contractor's record keeping for explosives and blasting logs.
20. Review monthly blasting report.
21. Document on the CA-EW-9, CA-EW-10, CA-EW-11 and the CA-D-2. Do not repeat information on other forms listed unless necessary.