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Tract 37803 FUTURE GRADING PLANS
Perris, CA

ASSESSMENT OF ROCK BLASTING IMPACTS AND RECOMMENDED PRACTICES

SEP 2020

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1.0 INTRODUCTION AND SCOPE

ABA Builders, Inc. (ABA) is designing a residential homes development Project on Tract 37803 in Perris, CA.

The site is underlain by granitic rock with outcrops scattered around site. The rock is weathered varying degrees and the use of controlled blasting methods may be required to excavate the harder areas. Excavations will include mass rock excavations to grade the site, trench excavations for utilities, and drainage basins for water collection.

Concerns about rock blasting in urban areas include control of vibration, noise, dust, flyrock and other impacts.

Information and clarifications in this review include:

1) Types of explosives that will be used.
2) Drilling methods, bore hole diameter, depth of borehole, number of holes per shot, stemming, burden, weight/volume (density) of explosives, and initiation methods.
3) Frequency of blasting and amount of material produced per blast.
4) The control of ground movement and flyrock.
5) Analysis of blast-induced ground vibrations and noise impacts on surrounding uses, including neighbors to the work and the environment.
6) Analysis of drilling-induced ground vibrations and noise impacts on all surrounding uses, including wildlife.
7) Analysis of blasting-induced emissions and dust.
8) Recommendations for minimizing any potential drilling and blasting impacts, as appropriate.

In response to the need for a blasting impacts analysis, ABA retained Gordon F. Revey (author) of REVEY Associates, Inc. (RAI) to evaluate how future blasting at the site can be controlled to protect people, structures, utilities and environmental resources on and near the site. Where appropriate, specific mitigation measures to prevent or minimize blasting impacts are recommended. All calculations and predictions regarding blast-induced effects made in this evaluation presume recommended blasting limitations will be applied as recommended.

Due to Covid 19 travel concerns, the author has studied the site via Google Earth and Google Maps. Note that the author has good familiarity with the area and the conditions of the granitic rock in and around Perris CA. Several years ago, the author developed specifications and oversaw blasting of over 1,000,000 cubic yards of rock at the Perris Dam Upgrades Project for the CA Department of Water Resources.

The evaluations and recommendations herein are based on the author's prior experience with similar blasting operations.

The igneous granitic rock in Perris CA varies in composition from granodiorite to tonalite and diorite. In general, these rocks are equigranular, medium-to-coarse grained, with irregular anhedral to subhedral biotite and hornblende crystals. Xenolithic inclusions of quartz-biotite schist are also occurring within some areas of the granites.

Based on prior experience of the author in similar rock formations, weathered rock within 10 or so feet of the ground surface might be removed by mechanical methods with dozers equipped with ripper shanks or by large excavator buckets with hardened teeth. The use of controlled drill-blast methods would likely be needed to fragment harder rock in excavations planned for site grading and utility trenching.

The general location of this development planned for Tract 37803 located north of W San Jacinto Avenue and west of North A Street in Perris CA, and property around the site are shown in Figures 1.1 and 1.2. An 11 x 17-inch detailed map of the entire Tract 73803 Project Site is provided in Attachment I. Pictures showing site conditions are provided in Attachment II.

Figure 1.1 – Perris CA Tract 37803 Location

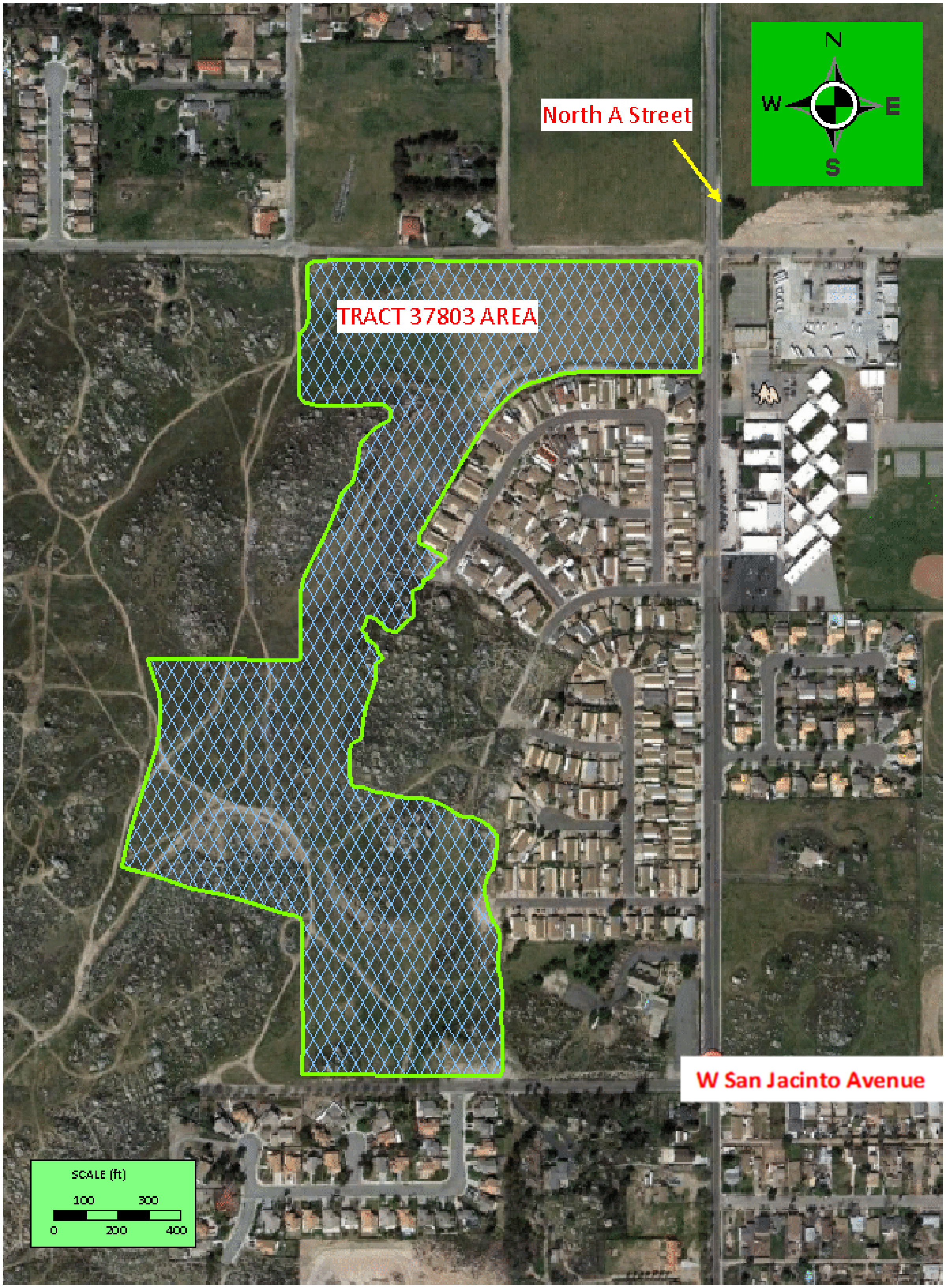


Figure 1.2 –Perris CA Tract 37803 Project Site Conditions Map

To acquaint the reader with the physical science of blast effects, including ground vibration and air-overpressure (noise), short technical summaries about physical blast effects are included in the body of this report. In addition, the International Society of Explosive Engineers (ISEE) Blast Monitoring Standards (Attachment II), and a list of blasting terms, definitions, and illustrations (Attachment III) are included.

For the purposes of this blasting impacts evaluation report, the closest structures and utilities that could be impacted by future controlled blasting operations are primarily residential homes, the First Congregation Church, overhead power lines, and other associated property and facilities surrounding the site.

2.0 BLAST EFFECTS, DAMAGE CRITERIA AND HUMAN RESPONSE

Before analyzing potential impacts of the blasting operations at the Tract 73803 Project, a general technical review of the physical effects of blasting, prediction methods, damage criteria, and human response are provided in subsections 2.1 through 2.6. Specific blast-induced vibration and air-overpressure limits for future blasting operations at the Tract 73803 Project are recommended in Section 2.7.

When explosive charges detonate in rock, they are designed so that most of the energy is used in breaking and displacing the rock mass. However, some of the energy can also be released in the form of transient stress waves, which in turn cause temporary ground vibration. Detonating charges also create rock movement and release of high-pressure gas, which in turn induce air-overpressure (noise), airborne dust and audible blast noise.

In the very-near zone, crushing usually occurs in the rock around the charge for to distance of approximately one-charge-diameter. Beyond the plastic crushing zone, the rock or ground is temporarily deformed by elastic strain waves. For some distance, tangential strain intensity exceeds the rock’s strength and new fractures are created. Radial cracks are created in rock around detonating charges by induced strain exceeding the rock’s tensile strength. These cracks generally do not extend farther than 26 charge radii (Siskind, 1983). For instance, if the diameter of the charge is 4.0 inches, radial cracks might extend 52 (4/2 x 26) inches into adjacent rock. Surface rupturing of rock in shoulders of rock walls beyond blasts might also extend for this distance.

2.1 Vibration Ground Waves

Within and beyond the cracking zone, stress waves spread through the rock mass and along the ground surface. As shown in Figure 2.1, some waves pass through the "body" of the rock mass. Primary compression waves and shear waves are examples of body waves. Other surface vibration waves travel along the ground surface like the way waves travel along the surface of water. In an ideal isotropic and homogenous rock mass, wave energy would travel evenly in all directions. However, most rock masses are far from ideal, so wave energy is reflected, refracted, and attenuated by various geological and topographical conditions. The elastic properties of rock greatly influence vibration magnitude and attenuation rate. When seismic waves pass through the ground, ground particles oscillate within three-dimensional space. Soon after blasting has stopped, vibration energy dissipates, and the ground particles become still.

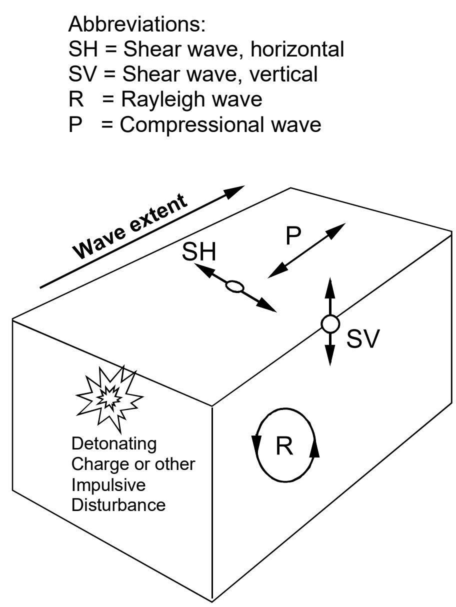


Figure 2.1 – Typical Vibration Waves

The characteristics of ground motion can be measured in several ways. These measures include:

- Particle displacement
- Particle velocity
- Particle acceleration
- Vibration frequency

Displacement is a measure of ground particle travel distance or location with respect to time. Particle velocity measures the speed of movement and acceleration is the rate of velocity changes. Vibration frequency is a measure of ground particle oscillations occurring per second of time. Frequency is reported in units of Hertz (Hz), which is equivalent to cycles per second.

Standard industry damage criteria and "safe levels" of ground motion are generally based on particle velocity and frequency of motion. The response of humans to ground motion is primarily influenced by ground motion velocity and duration of the motion. Vibration intensity is expressed as Peak Particle Velocity (PPV) or the maximum particle velocity of the ground. Since ground-shaking speeds are generally quite low, it is measured in inches per second (in/s).

Persons not familiar with vibration science often confuse particle velocity values with ground displacement. For instance, if a measured peak or maximum particle velocity is 0.25 inches, the ground has NOT moved a quarter of an inch. The actual temporary particle movement or displacement would be much less because in one second of time ground particles disturbed by blast vibration waves will oscillate back and forth many times in a second. Hence, frequency of motion is important because, unlike earthquakes where frequency of motion is quite low, cycles of ground particle shaking (frequency) caused by blasting usually occurs at 10 to 50 Hz. Since the ground particles are shaking back and forth or up and down so quickly, like running in place, movement is extremely small. As shown in Figure 2.2, the intensity and frequency of vibrating ground particles or changes in air-pressure can be determined when these events are measured and plotted with respect to time.

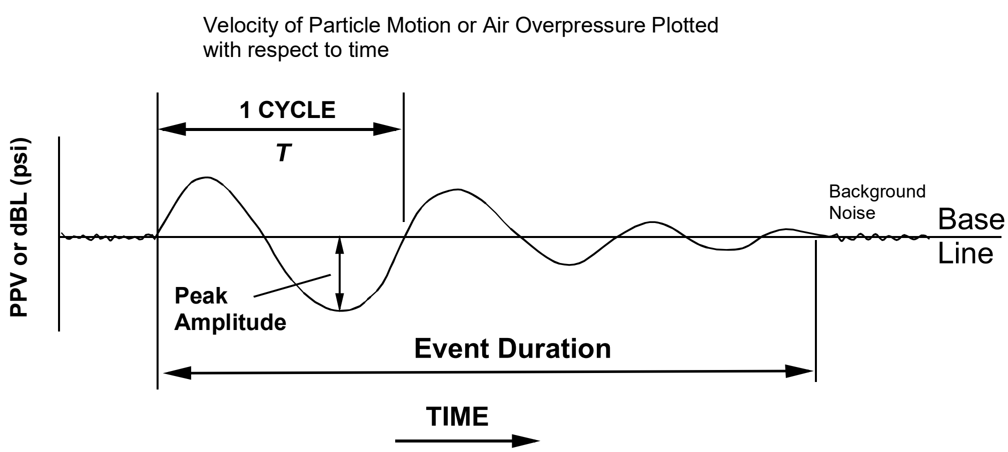


Figure 2.2 – Idealized Vibration or Air Overpressure Time—Intensity History Plot

At neighboring structures, potentially located 200 or so feet from blast areas at the Tract 73803, particle velocity should be limited to 0.5 in/s. At this distance, the frequency of motion would be around 40 Hz and the maximum elastic ground displacement would be around 0.002 in [0.5 / (2 x 3.14 x 40)], which is about four times less than the thickness of a human hair (≈ 0.008 in). It should also be understood that one particle of ground moving about 0.002 inches would not be separated by that distance from adjacent particles because, like ballroom dancers, oscillating particles of ground are just slightly out of step so the actual separation between them is extremely small.

2.2 Vibration Perception and Damage Criteria

The average person is quite sensitive to ground motion. As shown later in Figure 2.6, levels of blast-induced transient ground motions, lasting 2 seconds or less, with intensities as low as 0.02 in/s can be detected by the human body when background noise and vibration levels are low.

In Report of Investigations RI 8507, the US Bureau of Mines (Siskind, 1980) recommended the safe ground motion limits defined by the curves shown in Figure 2.3. These limits, ranging from 0.5 to 2.0 in/s, are the basis for most regulatory blast-induced vibration levels in most State and federal jurisdictions throughout the United States. These limits are well below levels that will cause any form of damage.

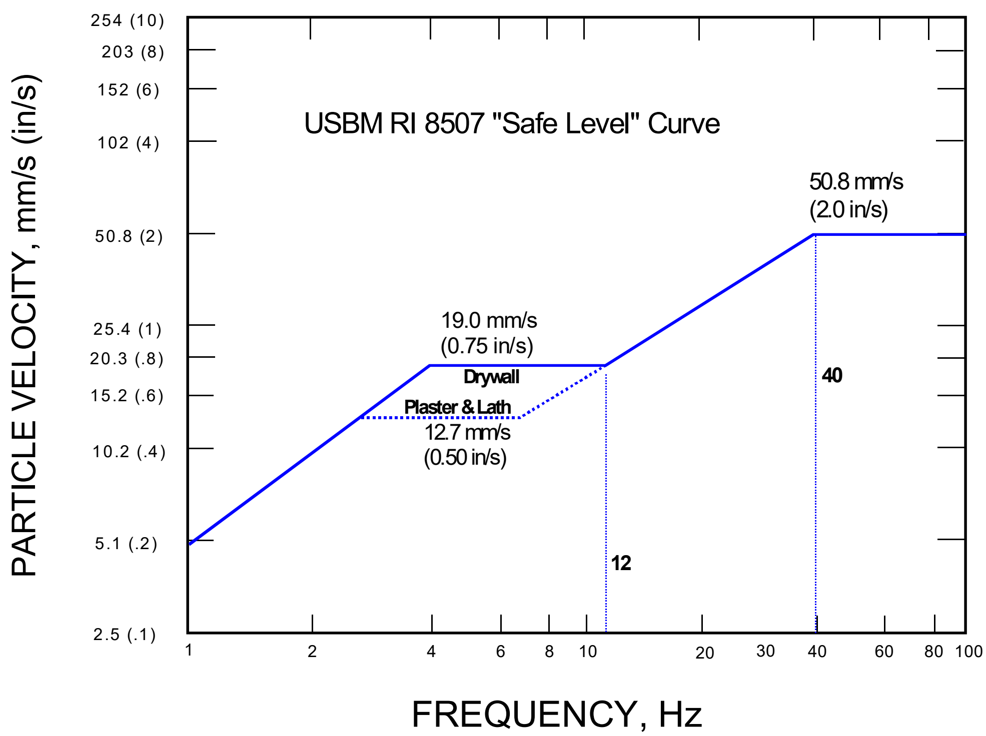


Figure 2.3 -- USBM "Safe Level" vibration curve from RI 8507

2.3 Blast Noise (Air-Overpressure)

The term "Blast noise" is misleading because the largest component of blast-induced noise occurs at frequencies below the threshold-of-hearing for humans (16 to 20 Hz). Hence, the common industry term for blast-induced noise is "air-overpressure". As its name implies, air-overpressure is a measure of the transient pressure changes. These low-intensity pulsating pressure changes, above and below ambient atmospheric pressure, are manifested in the form of acoustic waves traveling through the air. The speed of sound varies in different materials, depending on the density of the medium. For instance, pressure waves travel at the speed of 4,920 ft/s (1,500 m/s) in water, whereas, in air they travel at only 1,100 ft/s (335 m/s) because air has a lower density.

When calculating maximum air-overpressure values, the absolute value of the greatest pressure change is used, regardless of whether it is a positive or negative change. The frequency of the air-overpressure (noise) is determined by measuring how many up-and-down pressure changes occur in one second of time. Blast noise occurs at a broad range of frequencies and the highest-energy blast noise usually occurs at frequencies below that of human hearing (<20 Hz).

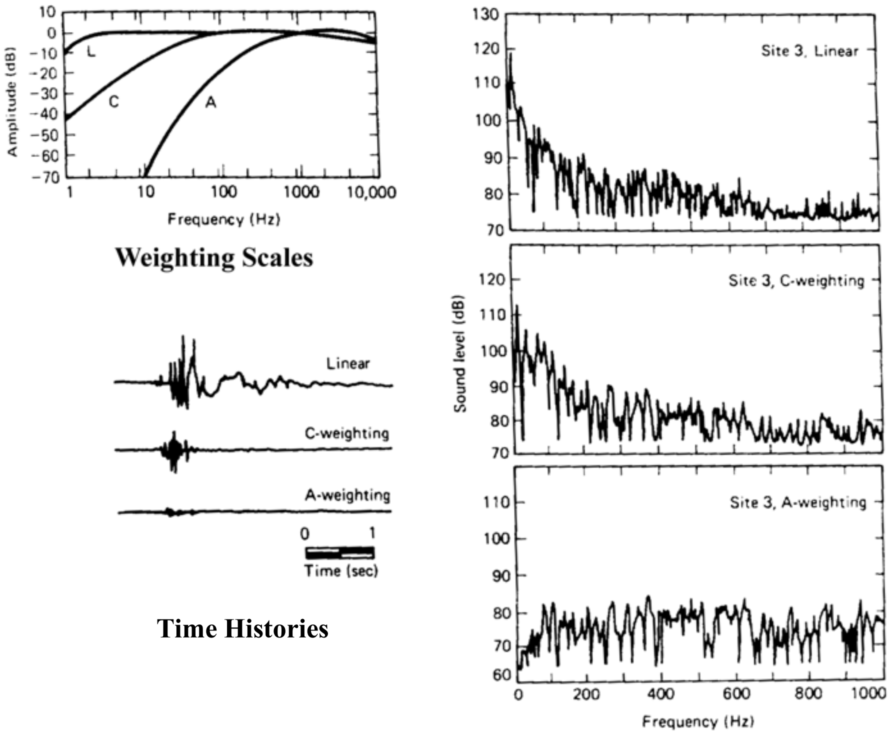
2.4 Air-Overpressure Measurement Scales

Regular acoustical noise measurements taken for the purpose of monitoring compliance with local noise ordinances almost always use A-weighted (dBA) and C-weighted (dBC) scales. Instruments used for these A and C-scale measurements filter out most of the air-overpressure occurring below a frequency of 20 Hz because humans cannot hear it and are generally not annoyed by it. Much of the air-overpressure frequency spectrum created by rock blasting occurs at frequencies below 20 Hz. Accordingly, seismographs used for blasting measurements are equipped with microphones and recording equipment that captures all air-overpressure fluctuations occurring from 2 to 200 Hz. These blasting measurements are called "linear-scale" measurements and the unit designation is “dBL.”

A significant amount of the energy in blast-induced air-pressure waves occurs at frequencies below 20 Hz. Thus, when A-weighted and C-weighted scales are used to record blast-induced noise, much of the event is filtered out and the reported intensity or decibel values are significantly less than what would be recorded by a linear scale 2-Hz-response microphone reporting results in dBL-scale. Differences between decibel scale measurements for individual blasts will vary depending on their unique frequency-intensity spectrums. Since full-range recording of blast-induced noise can only be done with linear (2-Hz response) instruments, it is imperative that all compliance specifications for blast-induced noise be expressed in “Linear” scale decibels (dBL).

In a study by USBM (RI 8485 – Siskind et al, 1980), researchers measured blast-induced noise at a common location using A-weighted, C-weighted and linear microphones. Comparable measurements taken about 800 feet from a blast, as shown in Figure 2.4, show that a linear peak noise of 120 dBL equates to only 112 dBC and 85 dBA.

Note that differences for individual blasts will vary depending on their unique frequency-intensity spectrums. Since full-range recordin*g* of blast-induced noise can only be done with linear scale instruments, it is imperative that all compliance specifications be expressed in linear scale (dBL).



After Siskind and Summers, (1974) **Fourier Frequency Spectra**

Figure 2.4 -- Effects of Weighted Filtering on Air-overpressure Records

The regulatory limit generally applied in State of California regulations, for air-overpressure measured with 2-Hz response seismographs is 133-dBL (0.0129 psi). For practical comparison, a 20-mph wind gust creates more strain in windows and walls than that caused by air-overpressure of this magnitude. Damage to old or poorly glazed windows does not occur until air-overpressure reaches about 150 dBL. More importantly, since the decibel scale is a logarithmic ratio, the actual air-overpressure at 150 dBL is 0.092 psi, versus 0.0129 psi at 133 dBL. Therefore, the actual air-overpressure at the 133 dBL limit, is over seven times (0.0917/0.0129) lower than the threshold damage level at 150 dBL. The relationship between air-overpressure expressed in psi and decibel-scale measurements are shown in Equation 2.1.

$$dB = 20\, Log_{10}\left({}^{P}\!/\!_{P_o} \right) \quad or \quad P = P_o\, 10^{\left({}^{dB}\!/\!_{20} \right)} \qquad \text{Equation 2.1}$$

Where: dB = decibels, P = overpressure (psi), P_o = Threshold of Human Hearing Pressure (20 microPascals or 2.9 x 10^{-9} psi).

NOTE: Due to the logarithmic ratios used to decibel values, seemingly small changes in decibel readings can equate to large changes in absolute air-overpressure (psi). Hence, all relative comparisons should be done in the base psi pressure units.

2.5 Blast Vibration Intensity Predictions

It is standard practice to use scaling relationships to predict vibration intensities at various distances. These relationships, based on similitude theory, are used to develop empirical relationships between ground vibration particle velocity, charge weight, and distance. Distance is scaled by dividing it by the square root of the maximum charge weight firing at any time within a blast. This single scaled distance variable can then be used to predict vibration intensity, which is essentially kinetic energy expressed as Peak Particle Velocity (PPV). The scaling relationship between PPV and scaled distance (D_s) is shown below in Equation 2.2.

$$PPV = K\left(D/\sqrt{W}\right)^m \quad or \quad PPV = K\left(D_s\right)^m$$

Equation 2.2

Where: PPV = Peak Particle Velocity (in/s)
D = Distance (ft)
W = Maximum Charge-weight-per-delay (lb)
K = Rock Energy Transfer Constant (K-Factor)
m = Decay Constant
D_s = Scaled Distance (ft-lb$^{-0.5}$)

Site-specific constants, ***K*** and ***m***, can be determined by performing a regression analysis of multiple PPV and D_s data pairs. In simple terms, for any given site, ***K*** is a measure of how much vibration energy is transferred to the ground near the explosive charge and ***m*** defines how fast the energy attenuates with distance.

A sample regression curve developed by the author when evaluating ground vibration impacts at the San Rafael Rock Quarry in Marin County CA is shown in Figure 2.5. When plotted in log-log scale, the exponential relationship between scaled distance and PPV generally follows a straight line with a negative slope (***m***) ranging from -1.2 to –1.7, and Y-intercept (***K***) values varying between 960 and 26, as defined by Oriard (1970). The ***K*** value (amount of energy at the source) is higher when charges are more confined and/or rock has a high stiffness ratio (modulus of elasticity).

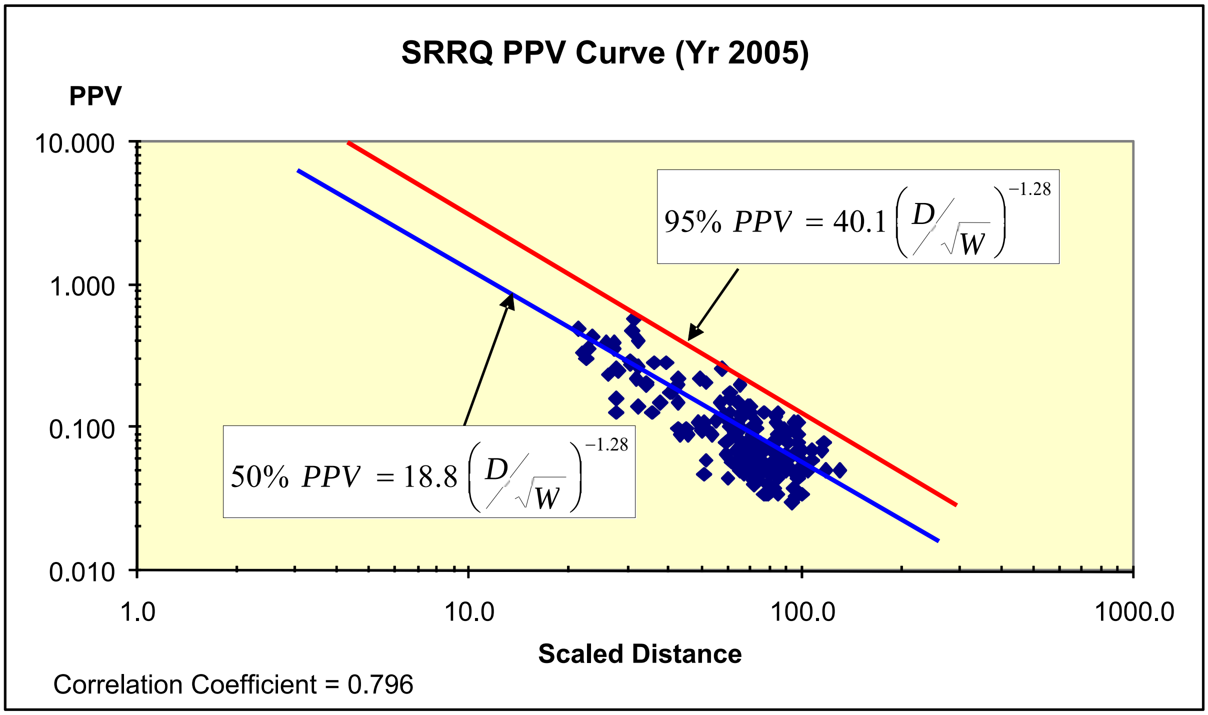


Figure 2.5 – Vibration attenuation curve for San Rafael Rock Quarry – Marin County, CA

When site-specific historical data is not available, the K factor value can be estimated based on physical rock properties and degree of blast confinement. From the author's past experience, for blasts in the granitic rock formations at the Tract 73803 Project site, a prediction equation with a ***K***-factor of 240 and attenuation constant of -1.6 can be used to predict vibration intensities or PPV at various locations of concern. With this cautiously high K-factor, predicted levels of vibration will likely be higher than actual values measured at similar scaled distances. The resulting prediction equation, which is used in the site-specific evaluations in Section 4 of this report, is shown Equation 2.3 below.

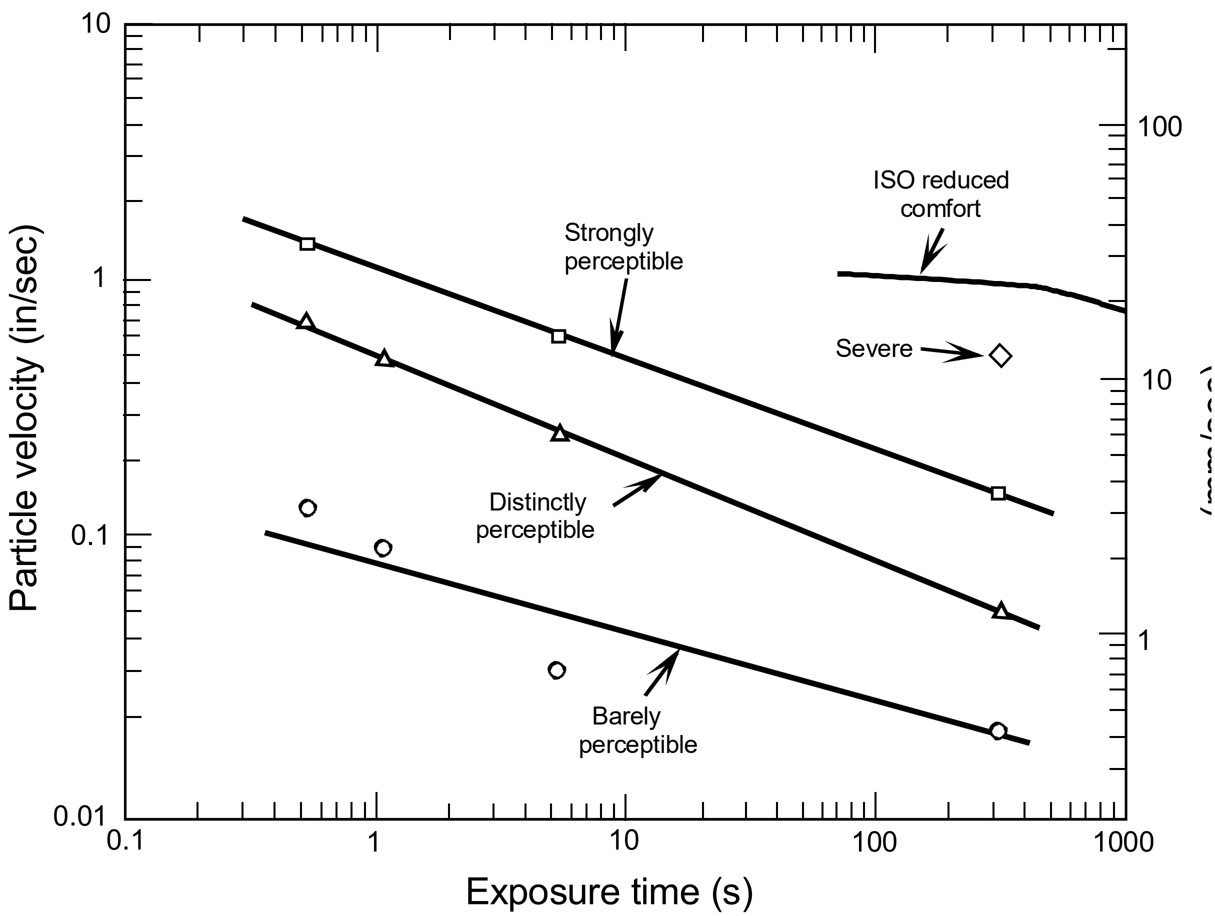
$$PPV = 200\left(D/\sqrt{W}\right)^{-1.6}$$ Equation 2.3

.

Where: PPV = Peak Particle Velocity (in/s)
D = Distance (ft)
W = Maximum Charge-weight-per-delay (lb)
K = Rock Energy Transfer Constant (K-Factor)
m = Decay Constant
$D_s = (D/W^{1./2})$ = Scaled Distance ($ft\text{-}lb^{-0.5}$)

2.6 Human Response to Transient Vibrations

In addition to concerns about vibration damage, under certain conditions, humans and animals can be startled or annoyed by blast-induced ground vibration. Research has also shown that the human response to transient vibration, like those caused by blasting, varies depending on exposure time and the intensity of the motion. Response curves defining how humans respond to transient vibrations based on these variables are shown in Figure 2.6.



Human response to transient pulses of varying duration after Wiss and Parmalee (1974)

Figure 2.6 – Human Response to Transient Vibration

2.7 Recommended Vibration and Air-Overpressure Limits

Based on prevailing blast-vibration control practices used in California and throughout the United States, regulators and blasting engineers develop vibration and noise limits that will: 1) prevent damage to structures and utilities and 2) minimize annoyance to neighbors.

Residential Buildings:

Based on human response issues and the author's experience at many blasting operations, it would be wise to plan on limiting PPV at all offsite occupied residential or similar community structures to 0.5 in/s at all frequencies of motion. Despite studies like RI 8507 (Siskind, et al, 1980) that indicate that higher PPV levels are safe when frequency of motion is higher, allowing higher limits is impractical because complaints and community problems would be unacceptable due to human response factors.

For planned rock blasting work, existing residential buildings might be located within 200 or so feet of blasts. Blasters can use standard methods to reduce charge-per-delay as needed to design and execute compliant blasts. For the expected site conditions, to keep PPV below 0.5 in/s, the minimum scaled distance should be 42.5 ft/lb$^{1/2}$. At a distance of 200 feet to a residential structure, maximum charge-per-delay would be 22 pounds [$(200/42.5)^2$]. At 100 feet, the charge would be reduced to 5.5 pounds [$(100/42.5)^2$].

It is important to note that the recommended target of keeping PPV below 0.5 in/s is NOT a damage threshold. The first-seen damage in homes occurring in the form of cosmetic cracking in drywall or plaster walls of homes would generally not occur until PPV exceeds 4.0 or in/s. Again, the much lower limit of 0.5 in/s is recommended to control negative perceptions of neighbors to the work.

Air-Overpressure Limit:

As described earlier in the technical summary regarding air-overpressure, the regulatory limit generally applied in State of California regulations, for air-overpressure measured with 2-Hz response seismographs is 133-dBL (0.0129 psi). This standard safe limit for structures of all types, based on research by the US Bureau of Mines (RI 8485 --Siskind et al, 1980), should be applied for all future blasting at the Tract 73803 Project.

3.0 IMPACTS OF BLASTING AT THE TRACT 73803 PROJECT AREA

To predict potential effects of blasting, blasting engineers must first establish what types of explosives would be used for the blasting and to define reasonable limitations regarding the scale of blasting and criteria used to control blasting impacts.

Since rock blasting at this site with good drainage will likely be dry, blasters could use bulk ANFO as the primary explosive charge. This bulk blasting agent is a mixture, by weight, of approximately 6% No. 2 Diesel Fuel and 94% ammonium nitrate. For blasts located within 200 feet of structures, blasters should use cartridge explosives to provide better control over charge weights.

For vibration control, blasters often use separately delayed charges within each hole. By so doing, the charge-per-delay and intensity of ground vibration is reduced. Typical charge configurations are shown in Figure 3.1.

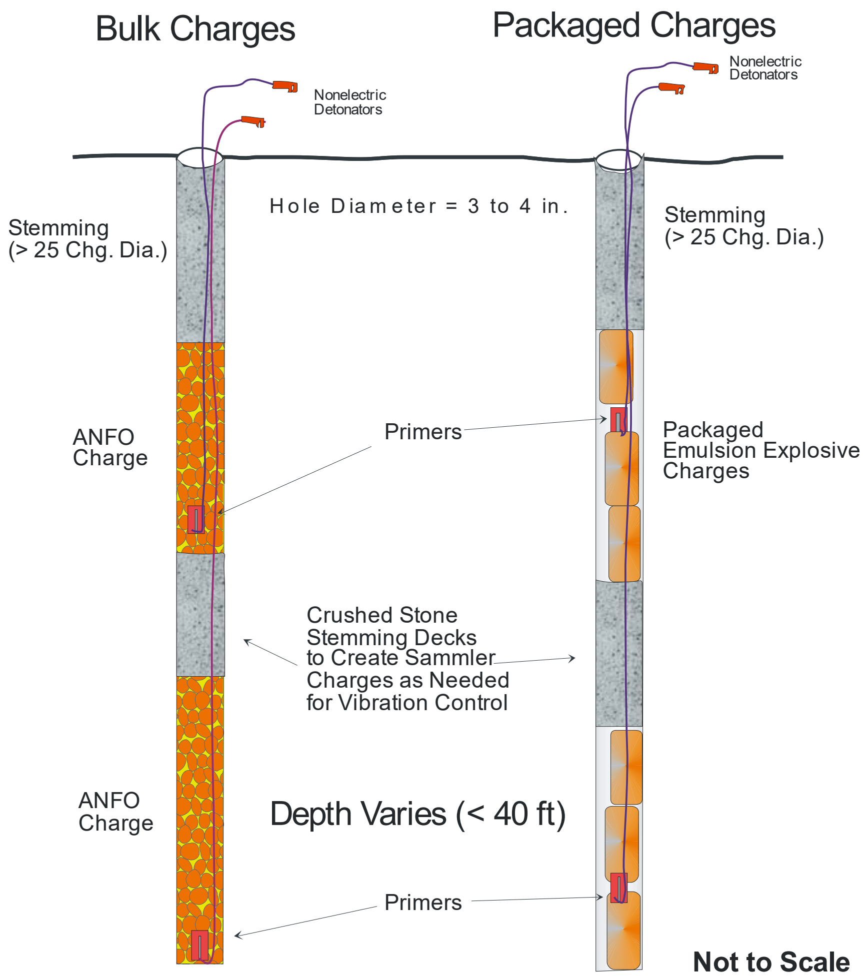


Figure 3.1 – Typical Charge Configurations for Blasting at the Tract 73803 Project

For the purpose of controlling environmental impacts of the blasting at the Tract 73803, the author specifically recommends the following blast design restrictions be adopted in contractually-required specifications for the work:

1) Blast-hole diameter should not exceed 4.0 inches.
2 PPV should not exceed 0.5 in/s at residential property.
3) PPV should not exceed 4.0 in/s at buried utilities.
4) Maximum charge-per-delay should not exceed 50 pounds.
5) Minimum confining rock burden on all charges shall be at least 25 charge-diameters.
6) All charges shall be stemmed with at least 25-charge-diameters of clean crushed stone.

7) Maximum weight of explosives used in individual blasts should not exceed 10,000 pounds. With rock densities of approximately 2.4 tons/yd^3 or less, quantity of rock per blast would not exceed 24,000 tons.
8) Height of blasted rock benches should not exceed 20 feet.
9) Rubber-tire and Steel-cable blasting mats or three feet of soil cover should be used to control movement of blasted rock and ground for all blasts located within 200 feet of all active overhead power lines.

Blasting terms in this report and illustrations that explain them are included in Attachment III.

All assessments made in this report assume that typical blasts will have 200 holes or less and ABC Builders Inc. will adopt the blast design restrictions and best management practices summarized on Page 19 .

3.1 Impacts on Water Resources

From the author's experience at many other blasting operations throughout the United States, concerns about blasting impacts on water resources have involved physical damage to existing water wells, aquifers, or chemical contamination of ground water. A discussion of these potential physical and chemical impacts at the Tract 73803 Project site follows.

<u>Physical Damage to Water Resources</u>

In a study (RI 7901 – Siskind et al, 1983) conducted by the US Bureau of Mines (USBM), researchers set up tests designed to determine zone of physical damage caused by exploding charges confined in rock. In this study, core logs, borehole periscopes, permeability tests and various other measures were used to determine the extent of blast damage to adjacent rock not fragmented and removed by blasting.

Data from the study indicated that the extent of localized blasthole damage in the form of radial cracking is generally a function of radial charge diameter, explosive type, and rock characteristics. Maximum cracking generally extends no farther than 13-charge-diameters into rock.

At the Tract 73803 Project site, the maximum fracture radius blastholes with diameter not exceeding 4.0 inches, at 13-charge-diameters, would likely not exceed 52 inches or 4.3 feet. Since all water wells, pipes and in-ground utility lines are located 150 or more feet from expected blasting areas, the occurrence of any physical damage or disruption is extremely unlikely.

Blast-induced ground motion at any private wells located in residential areas where PPV is restricted to 0.5 in/s will be well below levels of concern. The normal PPV limit in ground around wells and buried pipes is generally limited to 5.0 in/s. Hence the factor of safety is ten (5.0 / 0.5).

Temporary blast-induced vibration waves passing through well casings and surrounding ground water will cause no changes to existing water levels or quality.

Chemical Contamination of Ground Water and Surface Water

Most commercial explosives contain 70 to 94% ammonium nitrate, by weight. If substantial amounts of explosives were spilled or incompletely detonated, rainwater would cause some amount of ammonia and nitrate to leach out and go onto into the ground. Over time, leached ammonia and nitrates would penetrate into ground water and can possibly be washed by rainwater over the ground surface and into surface and ground water resources. The U.S. EPA ambient water quality criterion is 0.02-mg/L free-ammonia and the drinking water criterion for nitrate as nitrogen ($NO_3^{-}N$) is 10-mg/L.

If best industry standards of care concerning clean-up procedures are used to recover any spilled ANFO, and charges are adequately primed with cast-booster primers, losses of ammonia and nitrates to ground water or flowing surface water would not even be measurable.

Since no open water is located near expected rock blasting areas at the Tract 73803 Area, it is reasonable to conclude that the proposed blasting in the Tract 73803 area will have no impacts on area water resources.

3.2 Impacts to Air Quality

Rock blasting operations can impact air quality in two ways: 1) gasses are released to the air, and 2) dust is created by movement of blasted rock and overlying soils.

Explosive makers carefully design the blends of fuels and oxidizers used in commercial explosives to minimize the occurrence of toxic fumes like carbon dioxide (CO) and oxides of nitrogen (NO and NO_2). When explosives are “oxygen-balanced” the primary gases created are water vapor (H_2O), carbon dioxide (CO_2), and nitrogen gas (N_2). When ANFO is blended using 5.7 to 6.0 % fuel oil mixed with ammonium nitrate pellets, is at or near its ideal oxygen-balance. Emulsion explosives are similarly designed. In any case, soon after blasting, levels of oxides of nitrogen and carbon dioxide quickly dissipate to levels that are well below Threshold Limit Values (TLV). The author knows of no cases where toxic fumes generated by blasting operations operating with constraints like those recommended herein have caused any harm to humans or measurable impacts to wildlife or their habitat. The author is confident that gases produced by blasting operations at the Tract 73803 Area will cause no harm.

Dust is a bigger issue. In dry climates like that at the Tract 73803 Project site, dust created by blasting can be blown offsite. At the Tract 73803 Project, if wind gusts at speeds of 15 mph or greater, windblown dust could impact offsite structures. Blasting work should not be planned for days when wind speed is 15 mph or greater. When blasting does occur, dust can be mitigated by spraying water onto blast areas to wet the ground surface for at least three hours before blasting. ABC should contractually require contractors to apply the recommended dust control procedures.

3.3 Impacts on Animals and the Environment

Coyotes, other mammals, and birds could be expected to range within land on and around the site. Domestic animals will also inhabit neighboring residential areas.

About 25 years ago the author participated in a controlled study regarding the impacts of blasting on a variety of animal species conducted by animal biologists at the Washington Park Zoo in Portland, Oregon. In this study, researchers evaluated the effects of nearby (as close as 500 ft) blasting noise and vibration on black rhinos, naked mole rats, elephants, spotted owls, snow leopards, red pandas and several other species (Hall et al, 1998). Elephants were specifically chosen for this study because they are known to communicate at infrasonic noise frequencies below human hearing range. The black rhinos were studied because zookeepers were concerned that blasting might aggravate the problems with a pair that was unsuccessful at breeding during the year prior to the construction work. The physiological effects of blasting were evaluated by measuring the level of the stress hormone (cortisol) found in animal scat, before and after blasting. In addition, for the first six blasts, the physical reactions of the tested animals were observed when blasting occurred. The intensity of blast-induced ground motion in this study was as high as 0.68 in/s, which is more than six times higher than the 0.11-in/s level expected at nearest off-site range areas.

Maximum air-overpressure for this blasting was about 130 dBL (linear-scale) and ground motion reached about 0.25 in/sec, which are close to levels expected at neighboring land areas near the Tract 73803 Project. The researchers noted that the tested animals noticed the first blast or two. However, they quickly acclimated to the noise and vibration. The researchers concluded that the tested animals experienced no long-term negative effects from the levels of noise and vibration produced by the construction blasting.

From the author's personal experience, white-tailed deer were observed, on many occasions, within several hundred feet of an open-air explosive testing range at the former Atlas Powder Company in Tamaqua, Pennsylvania. The peak air-overpressures, during unconfined explosive tests, often exceeded 145 dBL. When blasts were detonated the deer might casually lift their heads and look toward the test site. However, they never ran away or appeared otherwise bothered by the loud noise. It was obvious that, like the animals at the Metro Washington Park Zoo in Portland, Oregon, the deer had become acclimatized to the blasting noise.

Measurements reported by the US Department of Transportation (USDOT, 1974) have found that rock drills with top hammers used to bore holes for blasting typically generate a peak A-scale noise of 98 dBA, Leq (loudness equivalent) at 50 feet. The drills that would be used for this work have down-hole hammers and would generate noise with levels below 90 dBA at 50 feet. At distances of 200 or so feet to nearest offsite structures, the level of noise would be noticeable. Hence, it would be wise to prohibit rock drilling during nighttime hours or on Sundays and holidays.

Based on the referenced studies and observations of the author at other projects, rock blasting at Tract 37803, conforming to the restrictions recommended herein would have little or no impact on domestic or wild animals near the site or on neighboring properties.

3.4 Impacts to Neighboring Homes or Other Community Buildings

If ABC Builders Inc. adopts and assures the application of the limitations recommended in this report, as summarized in Section 4.0, rock blasting work can be done without damaging offsite structures.

3.5 Impacts to Buried Pipes and Utilities

Since PPV in ground near residences and nearby wells and water supply pipes is limited to 0.5 in/s, it is extremely unlikely that blast-induce ground motion would have any impact whatsoever on well casings, pumps, water supply pipes or other utilities located near homes. New buried utilities located near roadways built in the Tract 37803 site will be protected by the 4.0 in/s PPV limit.

3.6 Impacts to Overhead Powerlines

Overhead powerlines will likely pass over some of the rock blasting areas. Accordingly, blasting work must be done with extra care to assure flyrock does not impact the powerlines. To assure this result, charges located within 200-horizonatal feet of powerlines should be covered with blast mast. All charges should also be confined with stemming with height of at least 25-charge-diameters.

3.7 Impacts to Rock Slopes

Design plans indicate the grade of excavated slopes in the Tract 73803 will be sloped 2:1 (H:V) or shallower. After blasting, slopes would be scraped clean with mechanical equipment so it is extremely unlikely that blasting will have any impact on the stability of the shallow slopes built into hard rock formations.

4.0 SUMMARY OF RECOMMENDED BLASTING CONTROLS

A summary of the all the specific blasting controls recommended to protect existing and future structures and utilities, and minimize annoyance, from blasting operations for the Tract 73803 blasting work follow.

1) Blast-hole diameter should not exceed 4.0 inches.

2) Charge-weight-per-delay should not exceed 50 pounds.

3) Minimum confining rock burden on all charges shall be at least 25 charge-diameters.

4) All charges shall be stemmed with at least 25 charge-diameters of clean washed crushed stone.

5) No more than 10,000 pounds of explosives should be used in individual blasts.

6) Height of blasted rock benches should not exceed 20 feet.

7) Rubber-tire and Steel-cable blasting mats or three feet of soil cover should be used to control movement of blasted rock and ground for all blasts located within 200 feet of all active overhead power lines.

8) ABC Builders Inc. should require contractors to apply spill cleanup procedures whereby measurable explosive spills are cleaned up immediately to prevent losses of nitrates and ammonia to the ground and neighboring water resources.

9) PPV at residential property should not exceed 0.5 in/s, and PPV on ground above buried utilities should not exceed 4.0 in/s.

10) Air-overpressure measured at nearest offsite structures should not exceed 133 dBL.

11) At least two seismographs should be deployed to measure PPV and air-overpressure at nearest structures or utilities of concern. All monitoring should conform to ISEE Guidelines provided in Attachment II.

12) Blast benches should be wetted with sprayed water for at least three hours to suppress dust and no blasting should occur when wind speed is greater than 15 mph.

13) All contractors and subcontractors performing blasting work at the Tract 37803 site should be contractually required to conform to the limitations described herein.

5.0 CONCLUSION

If ABC Builders Inc. adopts the practices and limitations proposed in this report, the author finds no issue that could prevent the execution of safe and environmentally acceptable blasting operations at the Tract 73803 Project.

6.0 REFERENCES

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ATTACHMENT I - TRACT 37803 SITE MAP

ATTACHMENT II - Tract 37803 Site Pictures

Looking Southwest at Tract 37803 from Exiting Property on Roadrunner Way

Looking North at Tract 37803 and First Congregational Church from San Jacinto Avenue

Looking South at Tract 37803 from Kimball Rd and Metz Road

International Society of Explosives Engineers

ISEE FIELD PRACTICE GUIDELINES FOR BLASTING SEISMOGRAPHS 2015

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This edition of *ISEE Field Practice Guidelines for Blasting Seismographs* was revised by the ISEE Standards Committee on July 2, 2015, and supersedes all previous editions. It was approved by the Society's Board of Directors in its role of Secretariat of the Standards at its July 31, 2015, meeting.

International Society of Explosives Engineers (ISEE) – Standards Committee Members[1]

Chairman, Kenneth K Eltschlager, U.S. Office of Surface Mining Reclamation and Enforcement
William Birch, Blastlog
Steven DelloRusso, Simpson Gumpertz & Heger Inc.
Alastair Grogan, Grogan Rock Consulting Ltd.
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Alan Richards, Terrock Consulting Engineers
Douglas Rudenko, Vibra-Tech Engineers, Inc.
Robert Turnbull, Instantel
Randall Wheeler, White Industrial Seismology
Board Liaison, Dr. Braden Lusk, University of Kentucky

[1]This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred.

Committee Scope: This Committee shall have primary responsibility for documents on the manufacture, transportation, storage, and use of explosives and related materials. This Committee does not have responsibility for documents on consumer and display fireworks, model and high power rockets and motors, and pyrotechnic special effects.

Origin and Development of ISEE Standards for Blasting Seismographs

One of the goals of the ISEE Standards Committee is to develop uniform and technically appropriate standards for blasting seismographs. The intent is to improve accuracy and consistency in vibration and air overpressure measurements. Blasting seismograph performance is affected by how the blasting seismograph is built and how it is placed in the field.

In 1994, questions were raised about the accuracy, reproducibility and defensibility of data from blasting seismographs. To address this issue, the International Society of Explosives Engineers (ISEE) established a Seismograph Standards Subcommittee at its annual conference held in February 1995. The committee was comprised of seismograph manufacturers, researchers, regulatory personnel and seismograph users.
In 1997, the Committee became the Blast Vibrations and Seismograph Section. The initial standards were drafted and approved by the Section in December 1999. Subsequently, the ISEE Board of Directors approved two standards in the year 2000: 1) ISEE Field Practice Guidelines for Blasting Seismographs; and 2) Performance Specifications for Blasting Seismographs.

In 2002, the Society established the ISEE Standards Committee. A review of the ISEE Field Practice Guidelines and the Performance Specifications for Blasting Seismographs fell within the scope of the Committee. Work began on a review of the Field Practice Guidelines in January 2006 and was completed in February 2008 to produce the 2009 edition. A revision to the Performance Specifications was started in 2009 and completed in 2011.

The ISEE Standards Committee takes on the role of keeping the standards up to date every 5 years. This document is the result of the latest effort by the ISEE Standards Committee to keep the standards up to date with current field techniques and technology.

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Disclaimer: These field practice recommendations are intended to serve as general guidelines and cannot describe all types of field conditions. It is important that the operator evaluate these conditions and obtain good coupling between the monitoring instrument and the surface to be monitored. In all cases, the operator is responsible for documenting the field conditions and setup procedures in the permanent record for each blast.

PREFACE

Blasting seismographs are used to establish compliance with Federal, state and local regulations and evaluate explosive performance. Laws and regulations have been established to prevent damage to property and injury to people. The disposition of the rules is strongly dependent on the accuracy of ground vibration and air overpressure data. In terms of explosive performance the same holds true. One goal of the ISEE Standards Committee is to ensure consistent recording of ground vibrations and air overpressure between all blasting seismographs.

ISEE Field Practice Guidelines
for Blasting Seismographs
2015 Edition

PART I. GENERAL GUIDELINES

Blasting seismographs are deployed in the field to record the levels of blast-induced ground vibration and air overpressure. Accuracy of the recordings is essential. These guidelines define the user's responsibilities when deploying blasting seismographs in the field and assume that the blasting seismographs conform to the ISEE "Performance Specifications for Blasting Seismographs" [3].

1. Read the instruction manual and be familiar with the operation of the instrument. Every seismograph comes with an instruction manual. Users are responsible for reading the appropriate sections and understanding the proper operation of the instrument before monitoring a blast.

2. Seismograph calibration. Annual calibration of the seismograph is recommended.

3. Keep proper blasting seismograph records. A user's log should note: the user's name, date, time, place and other pertinent data.

4. Document the location of the seismograph. This includes the name of the structure and where the seismograph was placed on the property relative to the structure. Any person should be able to locate and identify the exact monitoring location at a future date.

5. Know and record the distance to the blast. The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 meters or feet would be measured to the nearest tens of meters or feet respectively and a blast within 10,000 meters or feet would be measured to the nearest hundreds of feet or meters respectively. Where elevation changes exceed 2.5 horizontal:1 vertical, slant distances or true distance should be used.

6. Record the blast. When seismographs are deployed in the field, the time spent deploying the unit justifies recording an event. As practical, set the trigger levels low enough to record each blast.

7. Record the full time history waveform. Summary or single peak value recording options available on many seismographs should not be used for monitoring blast generated vibrations. Operating modes that report peak velocities over a specified time interval are not recommended when recording blast induced vibrations.

8. Set the sampling rate. The blasting seismograph should be programmed to record the entire blast event in enough detail to accurately reproduce the vibration trace. In general the sample rate should be at least 1000 samples per second.

9. Know the data processing time of the seismograph. Some units take up to 5 minutes to process and print data. If another blast occurs within this time the second blast may be missed.

10. Know the memory or record capacity of the seismograph. Enough memory must be available to store the event. The full waveform should be saved for future reference in either digital or analog form.

11. Know the nature of the report that is required. For example, provide a hard copy in the field; keep digital data as a permanent record or both. If an event is to be printed in the field, a printer with paper is needed.

12. Allow ample time for proper setup of the seismograph. Many errors occur when seismographs are hurriedly set up. Generally, more than 15 minutes for set up should be allowed from the time the user arrives at the monitoring location until the blast.

13. Know the temperature. Seismographs have varying manufacturer specified operating temperatures.

14. Secure cables. Suspended or freely moving cables from the wind or other extraneous sources can produce false triggers due to microphonics.

PART II. GROUND VIBRATION MONITORING

Placement and coupling of the vibration sensor are the two most important factors to ensure accurate ground vibration recordings.

A. Sensor Placement

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure. Sensor placement should ensure that the data obtained adequately represents the ground-borne vibration levels received at the structure. The sensor should be placed within 3.05 meters (10 feet) of the structure or less than 10% of the distance from the blast, whichever is less.

2. Soil density evaluation. The soil should be undisturbed or compacted fill. Loose fill material, unconsolidated soils, flower-bed mulch or other unusual mediums may have an adverse influence on the recording accuracy.

3. The sensor must be nearly level.

4. Typical practice is to point the longitudinal/radial channel towards the blast site. However, other sensor orientations are allowed.

a. For blast-by-blast sensor deployment, the longitudinal/radial channel should be pointed towards the closest blast hole. Records should indicate if this condition is met.

b. For multiple-blast sensor deployment, the azimuth (0-360 degrees, +/- 5 degrees) of the longitudinal/radial channel relative to true north should be recorded.

5. Where access to a structure and/or property is not available, the sensor should be placed closer to the blast in undisturbed soil.

B. Sensor Coupling

If the acceleration exceeds 1.96 m/s^2 (0.2 g), decoupling of the sensor may occur. Depending on the anticipated acceleration levels spiking, burial, or sandbagging of the geophone to the ground may be appropriate.

1. If the acceleration is expected to be:

a. Less than 1.96 m/s^2 (0.2 g), no burial or attachment is necessary.

b. Between 1.96 m/s^2 (0.2 g), and 9.81 m/s^2 (1.0 g), burial or attachment is preferred. Spiking may be acceptable.

c. Greater than 9.81 m/s^2 (1.0 g) , burial or firm attachment is required [7].

The following table exemplifies the particle velocities and frequencies where accelerations are 1.96 m/s^2 (0.2 g) and 9.81 m/s^2 (1.0 g).

Frequency, Hz	4	10	15	20	25	30	40	50	100	200
Particle Velocity mm/s (in/s) at 1.96 m/s^2 (0.2 g)	78.0 (3.07)	31.2 (1.23)	20.8 (0.82)	15.6 (0.61)	12.5 (0.49)	10.4 (0.41)	7.8 (0.31)	6.2 (0.25)	3.1 (0.12)	1.6 (0.06)
Particle Velocity mm/s (in/s) at 9.81 m/s^2 (1.0 g)	390 (15.4)	156 (6.14)	104 (4.10)	78.0 (3.07)	62.4 (2.46)	52.0 (2.05)	39.0 (1.54)	31.2 (1.23)	15.6 (0.61)	7.8 (0.31)

2. Burial or attachment methods.

a. The preferred burial method is excavating a hole that is no less than three times the height of the sensor [1], spiking the sensor to the bottom of the hole, and firmly compacting soil around and over the sensor.

b. Attachment to bedrock is achieved by bolting, clamping or adhering the sensor to the rock surface.

c. The sensor may be attached to the foundation of the structure if it is located within +/- 0.305 meters (1-foot) of ground level [5]. This should only be used if burial, spiking or sandbagging is not practical.

3. Other sensor placement methods.

a. Shallow burial is anything less than described at 2a above.

b. Spiking entails removing the sod, with minimal disturbance of the soil and firmly pressing the sensor with the attached spike(s) into the ground.

c. Sand bagging requires removing the sod with minimal disturbance to the soil and placing the sensor on the bare spot with a sand bag over top. Sand bags should be large and loosely filled with about 4.55 kilograms (10 pounds) of sand. When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.

d. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

C. Programming Considerations

Site conditions dictate certain actions when programming the seismograph.

1. Ground vibration trigger level. The trigger level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 1.3mm/s (0.05in/s).

2. Dynamic range and resolution. If the seismograph is not equipped with an auto-range function, the user should estimate the expected vibration level and set the appropriate range. The resolution of the printed waveform should allow verification of whether or not the event was a blast.

3. Recording duration. Set the record time for 2 seconds longer than the blast duration plus 1 second for each 335 meters (1100 feet) from the blast.

PART III. AIR OVERPRESSURE MONITORING

Placement of the microphone relative to the structure is the most important factor.

A. Microphone Placement

The microphone should be placed along the side of the structure, nearest the blast.

1. The microphone should be mounted near the geophone with the manufacturer's wind screen attached.

2. The microphone may be placed at any height above the ground [2].

3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.

4. If placed too close to a structure, the air overpressure may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Reflection can be minimized by placing the microphone near a corner of the structure. [6].

5. The orientation of the microphone is not critical for air overpressure frequencies below 1,000 Hz [6].

6. The microphone element must be kept dry to help maintain proper calibration and minimize the potential for corrosion. A common practice is to place a windscreen (typically provided by the manufacturer) on the microphone and cover it loosely with a thin plastic bag, or "rain shield." Other methods can be used to protect the microphone from moisture; however, the pressure around the microphone sensing element must be able to change in relation to the pressure change caused by the blast overpressure.

a. When using a plastic bag as a rain shield, the bag should be tied loosely around the microphone, allowing some exchange of air between the inside and outside of the shield. Completely sealing a rain shield could result in the following:

i. Condensation – water accumulates inside the shield. A small hole in the bottom of the shield can help mitigate this issue.
ii. Static Pressure – over time pressure could build in the shield.
iii. Rain Triggers – rain drops striking a tightly sealed shield will cause pressure pulses that could trigger the seismograph.

b. It is acceptable to keep microphones inside security boxes or other protective covers as long as the pressure change in the enclosure reflects the pressure change outside of the protective cover in the surrounding environment.

B. Programming Considerations

Site conditions dictate certain actions when programming the seismograph to record air overpressure.

1. Trigger Level – When only an air overpressure measurement is desired, the trigger level should be low enough to trigger the unit from the air overpressure and high enough to minimize the occurrence of false events. The level should be slightly above the expected background noise for the area. A good starting level is 20 Pa (0.20 millibars or 120 dB).

2. Recording Duration – When only recording air overpressure, set the recording time for at least 2 seconds more than the blast duration. When ground vibrations and air overpressure measurements are desired on the same record, follow the guidelines for ground vibration programming (Part II C.3).

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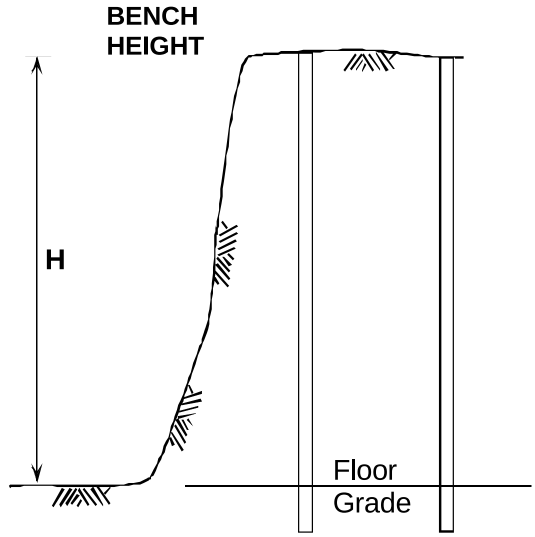
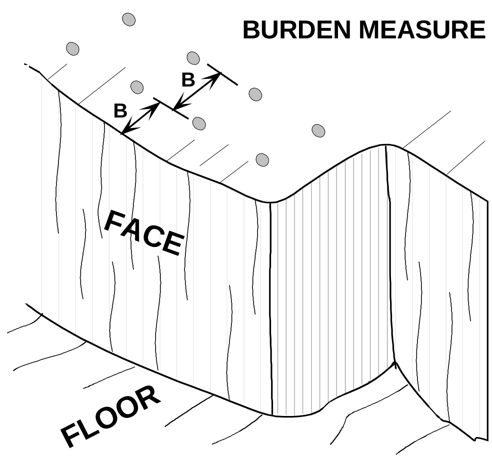
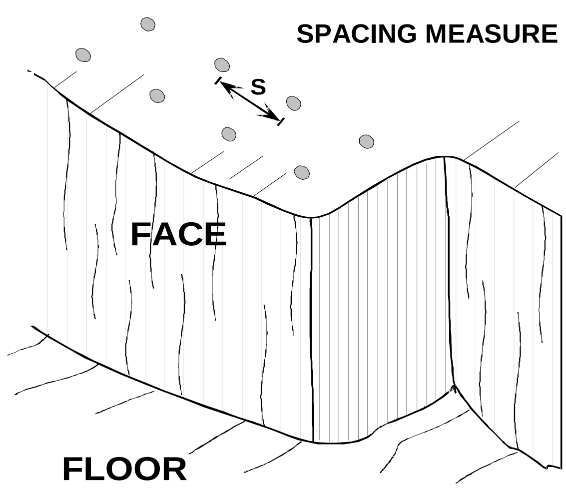
ROCK BLASTING DESIGN TERMS

Bench Height (H): is the vertical height of a rock wall or bench measured from the designed excavation floor or grade level to the top surface or crest of the rock bench.



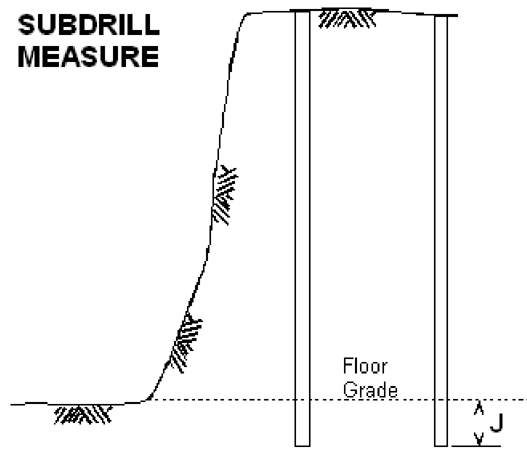


Burden (B): a broadly used term that generally defines the amount of rock between explosive charges and the nearest rock face or wall. Burden is the perpendicular distance measured between rows of blastholes drilled parallel to the longest open bench face. For adequate lateral relief, Burden (B) should generally be less than or equal to ½ the Bench Height (H). For adequate confinement and rock breakage, Burden (B) is generally 20 to 30 times the diameter of the explosive charge.

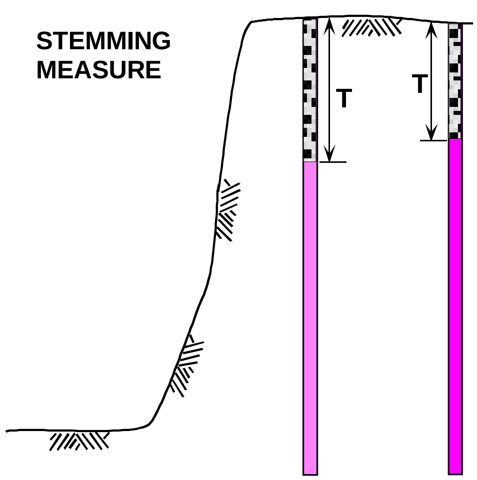


Spacing (S): is generally the distance measured between holes within rows of holes parallel to the major free face. Spacing (S) is generally 1.0 to 1.8 x Burden (B).

ROCK BLASTING DESIGN TERMS, Continued

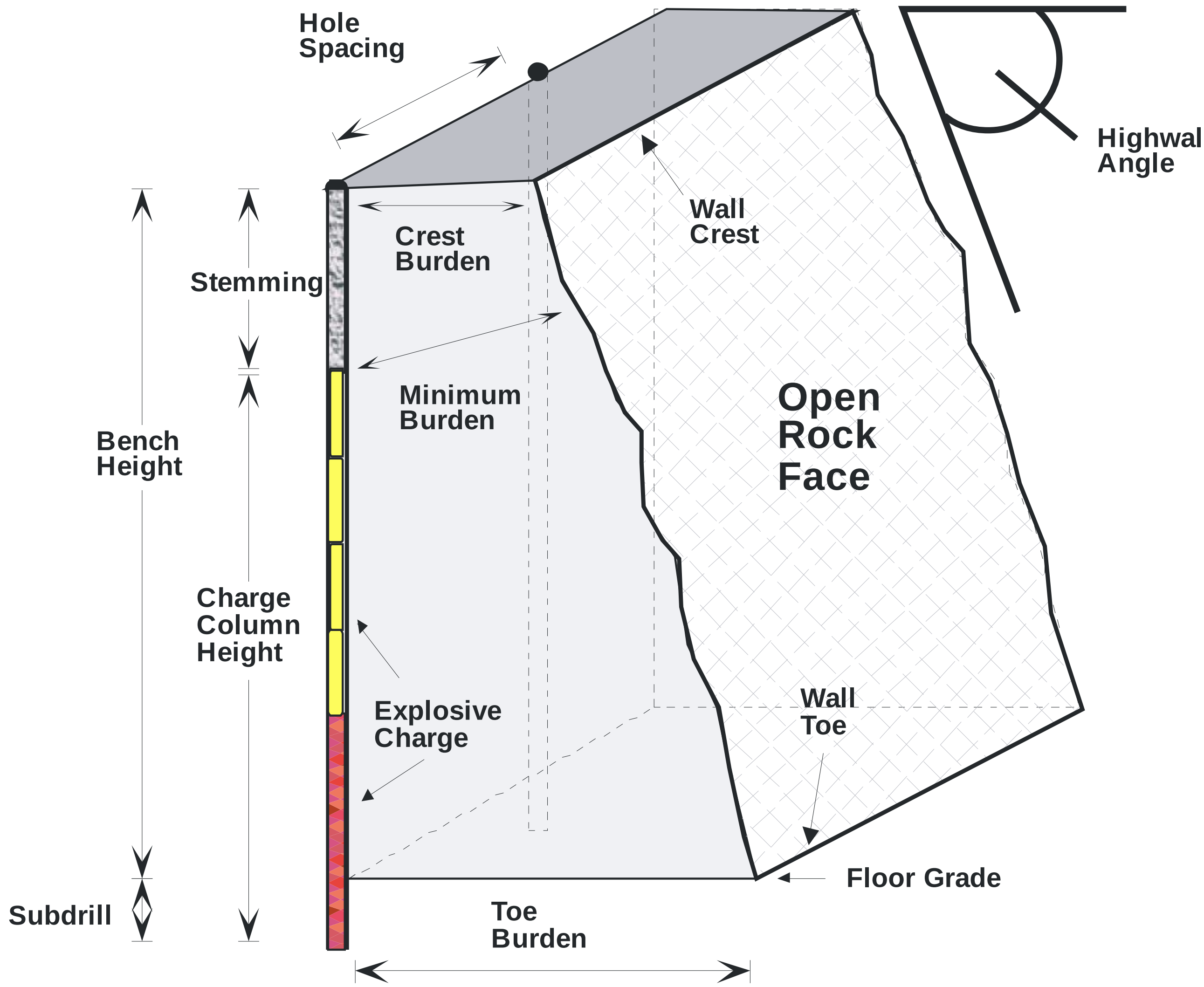


Subdrill (J): is the portion of blastholes drilled below the desired floor or grade elevation of the bench or rock that will be excavated after blasting. High spots of unbroken rock occur between the bottoms of blasted holes so explosive must be placed below the desired floor grade to allow complete excavation at that level. Minimum amount of Subdrilling (J) is generally 2.0 ft (0.7 m). When blasting is done against final horizontal rock surfaces including benches, foundation floors and spillways, no Subdrilling should be done to avoid rupture damage beyond the desired limits of the excavation.

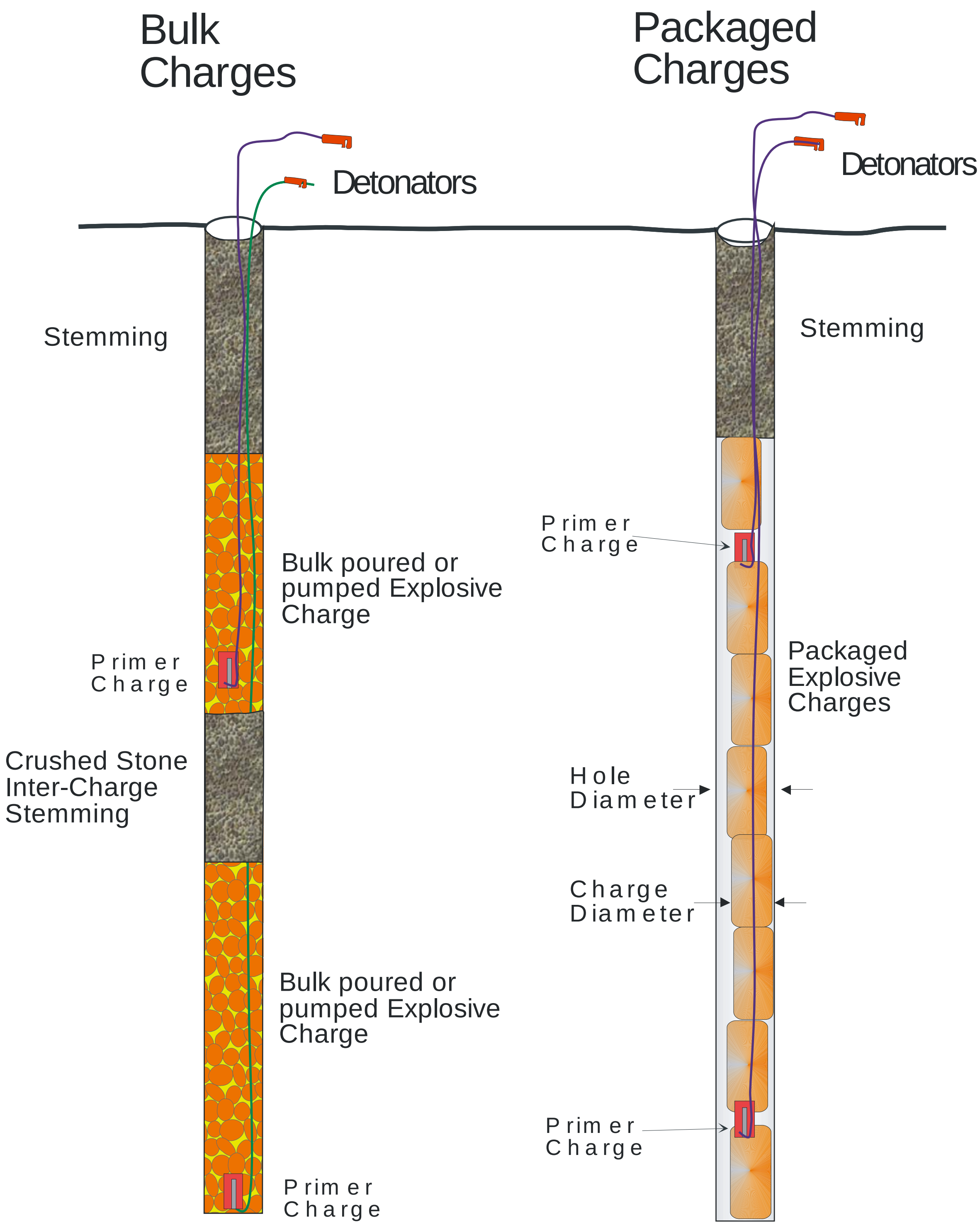


Stemming (T): is inert material placed in the collars of blastholes to confine explosive charges. Clean crushed stone is the most effective stemming material. Good charge confinement results when stemming (T) is at least 20 charge-diameters.

ROCK BLASTING DESIGN TERMS, Continued



ROCK BLASTING DESIGN TERMS, Continued



Not to Scale

ROCK BLASTING DESIGN TERMS, Continued

Powder Factor (PF):

Powder factors are relative measures of how much explosive energy is available to break a fixed quantity of rock. Explosive quantities are normally expressed in units of weight measured in either kilograms (kg) or pounds force (lb). Rock quantities can be expressed in units of weight or volume. When operations measure blasted rock in tons or metric tonnes, powder factors are normally expressed by ratios of explosive weight per ton or tonne. Quarries and mines express their production figures by tons or tonnes, so they calculate powder factors as:

$$\frac{\text{Explosive weight}}{\text{Unit rock weight}} \quad \text{in units of} \quad (\text{kg/tonne}) \text{ or } (\text{lb/ton})$$

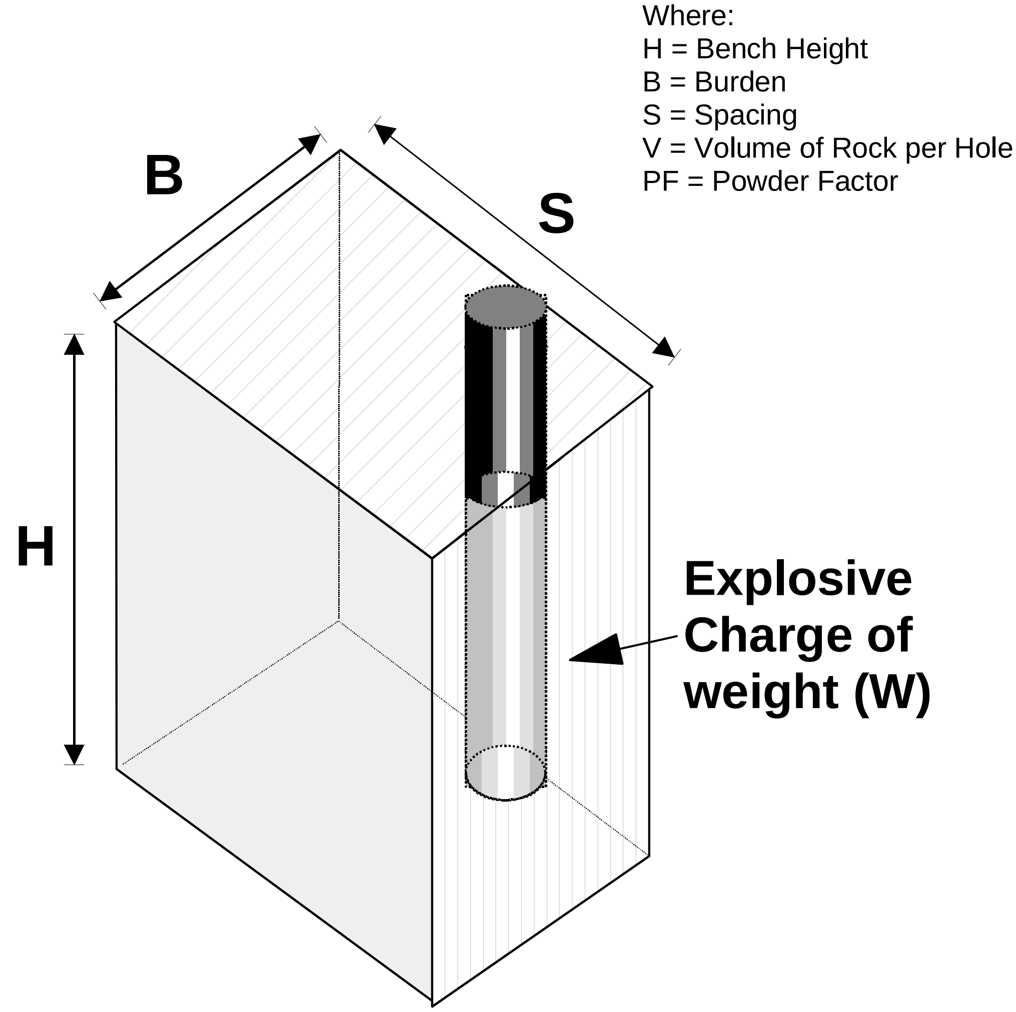
The quantities of rock excavated in construction projects are almost always measured by volume, so powder factors for this work are also related to unit volumes measured in either cubic meters (m^3) or cubic yards (yd^3). So construction powder factors are measured in:

$$PF = Ew/Uv$$

Where Ew = Explosive weight (lb) or (kg)
Uv = unit rock Volume (yd^3) or (m^3)

ROCK BLASTING DESIGN TERMS, Continued

Simplified Powder Factor Illustration



Rock Volume per hole (V) = B x S x H

Powder factor (PF) $= \frac{W}{V}$